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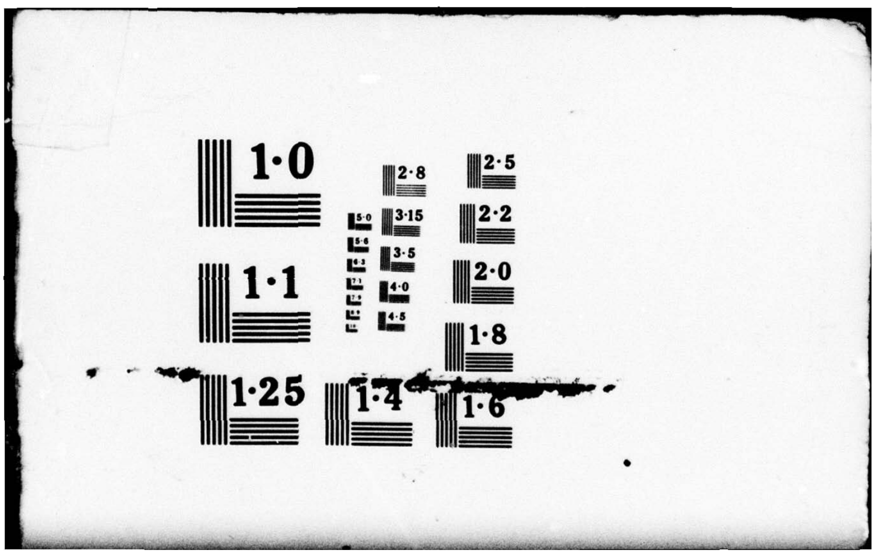
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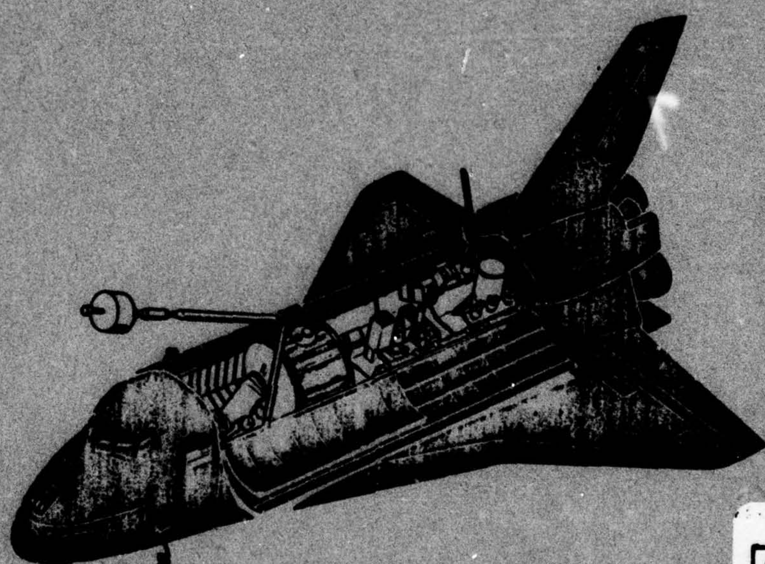
STS UTILIZATION STUDY

FINAL REPORT
30 DECEMBER 1977



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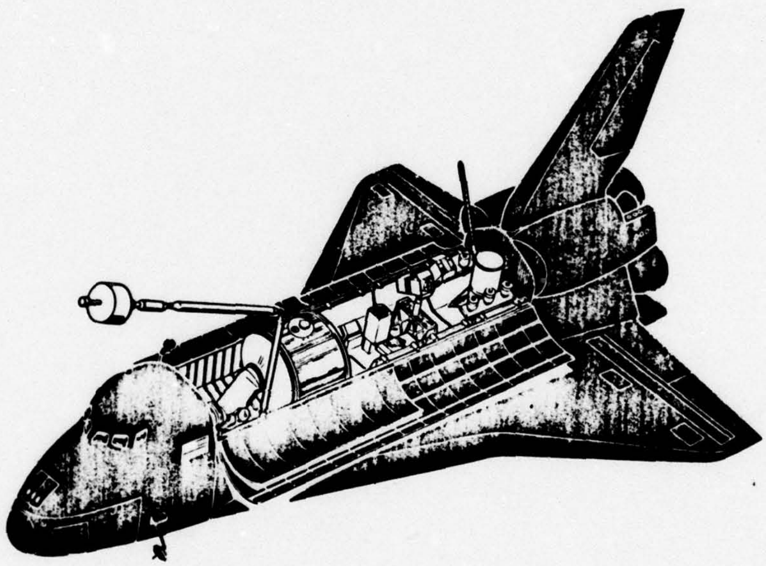

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A study was performed to identify those experiments from DoD laboratories that will be able to use the Space Transportation System (STS). Applicable experiments were assessed to determine the most effective carrier system within the STS. Design suggestions were made to improve experiment compatibility with the STS. The report describes the study and includes examples of the experiment assessments. It is concluded that a considerable amount of DoD space flight experimentation can be projected for the STS flight era. Most experiments will require one of the payload carriers, now under development, to interface with the Orbiter. Many will require the use of special flight support equipment such as a pointing system. In a specific area, it was found that there is basic materials research within DoD that might benefit from space experimentation.

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FOREWORD

This study was conducted for the United States Air Force, Space and Missiles Systems Organization (SAMSO), in accordance with the Statement of Work for the "STS Utilization Study." This report is submitted as partial fulfillment of Contract No. F04701-77-C-0112, CDRL Item 005A2.

The study was conducted under the direction of Major Carl Jund, Space Test Program Plans Division, with Mr. Larry Weeks, Aerospace Corporation, providing technical direction. The findings of this report should not be construed as STP acceptance of an individual experiment. It is still required that final approval be obtained from the Department of Defense through the use of DD Form 1721, Request for Space Flight.

The TRW Study Manager was Mr. Robert Elkins in the Space Systems Division of TRW Defense and Space Systems Group.

Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

Carl P. Jund

Carl S. Jund
Major, USAF
Chief, STP Plans Division

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INTRODUCTION AND SUMMARY

The Space Test Program provides the DoD community with opportunities to prove concepts and technology in space, and provide the means to qualify hardware for use on operational space systems. Dedicated boosters containing a variety of experiments and "piggyback" rides on other boosters, have been the means for providing a space environment up until the Shuttle era.

Because of the limitations of weight, size and budget, experimenters have competed for opportunities, and in many cases, valuable time has been lost because there have been many more experiments and equipment than could be accommodated within the STP framework.

The advent of the Shuttle provides expanded opportunities to evaluate performance of hardware and develop technology. Increased weight, volume and frequency of flights, coupled with the ability to retrieve hardware, open up areas of investigation previously unavailable.

Recognizing this expanded capability to perform experiments with the STS, the Space Test Program Office directed a study to reevaluate the technical needs of the DoD and determine the means for exploiting the added utility provided. The study conducted by TRW is summarized in this Final Report.

This report describes the study scope, the methodology used in performing the tasks comprising the study, the TRW organization that performed the study, examples of the assessments, and the results and conclusions drawn from the study.

Experiments which are candidates for space flight were evaluated to determine if the STS would provide the proper test bed for experimentation or qualification. In cases where the proper conditions were provided, an assessment was made to determine which of the available STS carriers would provide the best environment. Examples of these assessments are included in this report and illustrate several modes and environments which can be provided by the Space Transportation System. The versatility is illustrated by the various accommodation techniques demonstrated.

These assessments will provide insight for other experimenters, scientists and engineers to determine ways in which the STS may be used to provide a proper test bed for their field of interest.

SCOPE

The objective of the study was to identify experiments and concepts that use the added capability of the STS, assess the interface between the experiments, the STS and its various carriers, and develop design suggestions and/or modifications which provide an integrated approach with the Space Transportation System.

These assessments were performed at two levels of depth. The first, called "medium level assessments," provides an insight into the purpose of the experiments, outlines the assessments for "flying" on STS, provides design suggestions, operational restrictions, describes support equipment which may be needed, and considers the cost implications. If practical, a sketch was provided showing an artist's concept of an arrangement which satisfies the experiment needs.

The second category, or "low level" assessments, provides a very brief evaluation of the manner in which these experiments could be accommodated by the STS.

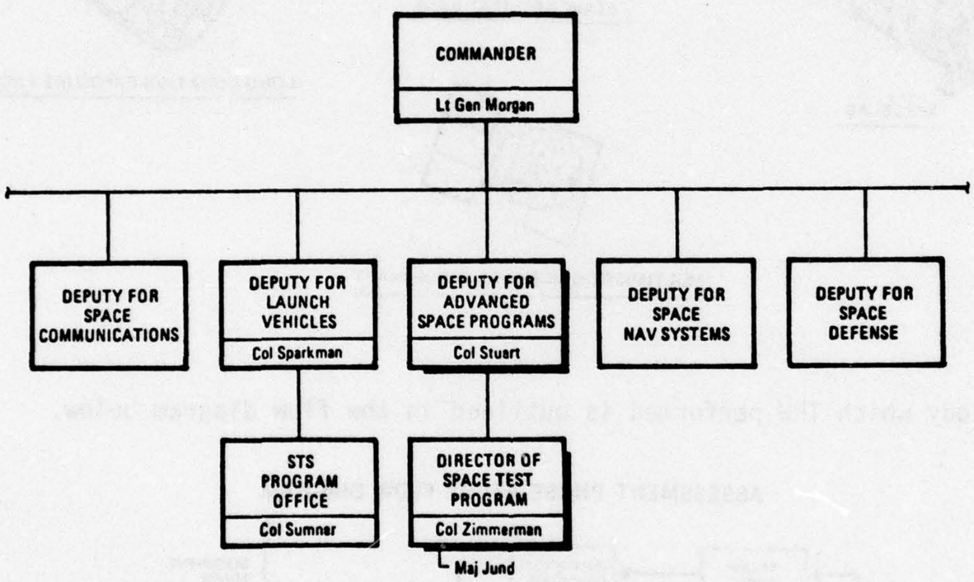
The assessments, background material, descriptions of the STS, Standard Test Rack, and performance characteristics of the Spacelab were compiled into a document which will be sent to all participating DoD agencies, "STS Utilization Study Experiment Assessments," SAMSO TR-77-188, dated 30 December 1977.

BACKGROUND/METHODOLOGY

The study was conducted under a contract issued by the Air Force Space and Missile Systems Organization (SAMSO), and directed by Major Carl Jund, the Manager of Plans for the Director of Space Test Programs, Col. Zimmerman.

The relationship is shown by the following organizational chart.

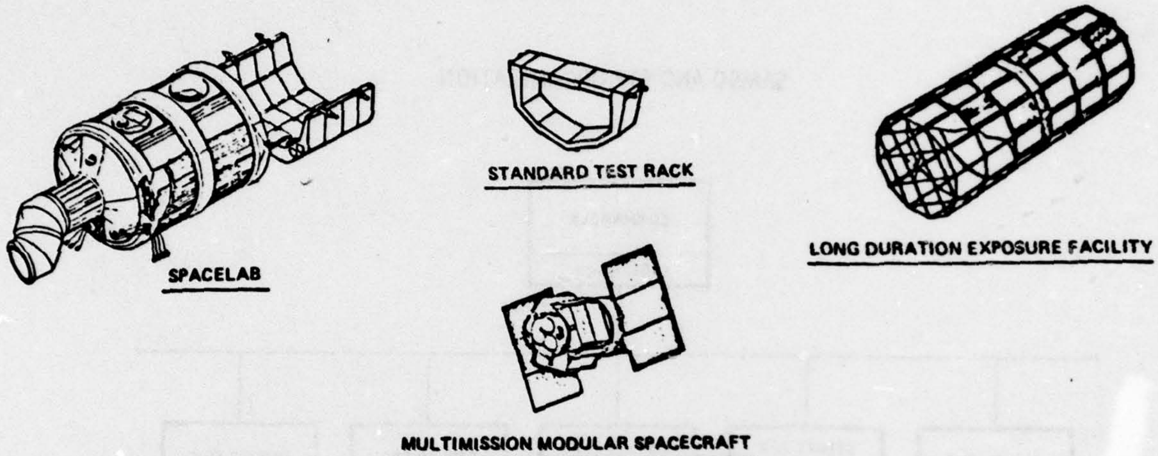
SAMSO AND STP ORGANIZATION



The role of the Space Test Program is to provide the means to conduct DoD space experiments and evaluate and qualify hardware for use on operational systems. This responsibility includes arranging for and providing the funds for the launch vehicle, launch operations and upper stages, if required. When a complement of experiments can be integrated on a single satellite, STP will contract for a spacecraft and manage that program from its inception through data retrieval.

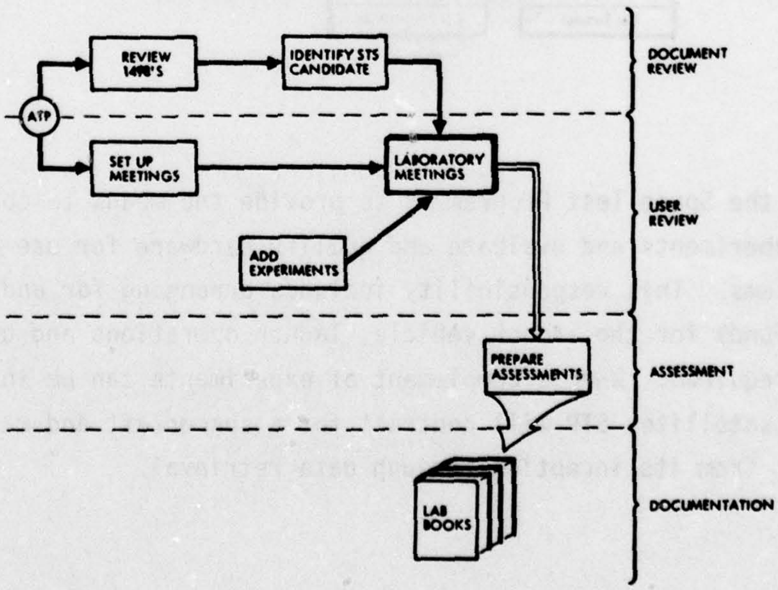
With the potential provided by the Space Transportation System, and the plan to utilize space on both NASA and DoD Shuttle missions, the opportunity to "fly" experiments will be vastly increased. The carriers which will be considered for DoD payloads are shown in the figure below.

POSSIBLE CARRIERS



The study which TRW performed is outlined in the flow diagram below.

ASSESSMENT PHASE STUDY FLOW DIAGRAM



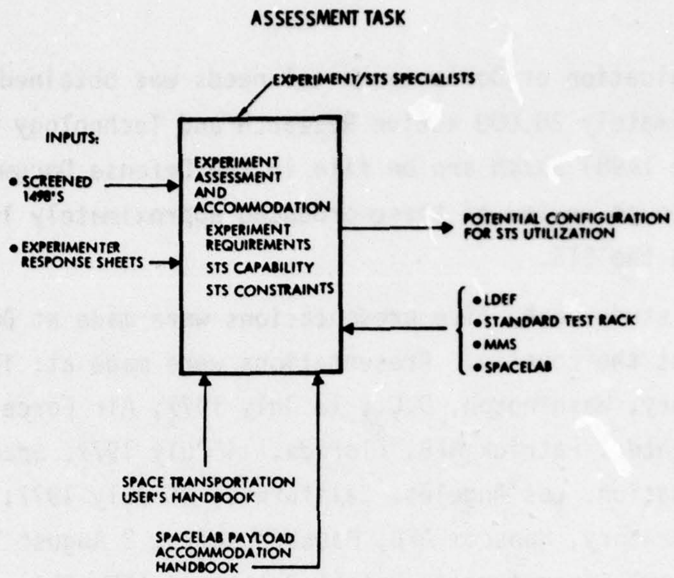
The initial evaluation of DoD's technical needs was obtained by screening the approximately 20,000 active Research and Technology Work Unit Summaries (Form 1498) which are on file in the Defense Documentation Center. A thorough review of these produced approximately 100 that were compatible with the STS.

As part of the study task, five presentations were made at DoD installations throughout the country. Presentations were made at: The Naval Research Laboratory, Washington, D.C., 12 July 1977; Air Force Technical Applications Center, Patrick AFB, Florida, 14 July 1977; Space and Missile Systems Organization, Los Angeles, California, 28 July 1977; Air Force Geophysics Laboratory, Hanscom AFB, Massachusetts, 2 August 1977; Air Force Aeronautical Laboratories, Wright-Patterson AFB, Ohio, 4 August 1977.

The purpose of these presentations was to acquaint the technical and management personnel within these agencies with the capability of the Space Transportation System, the added potential for experimentation which the STS provides and outline the study being performed. The participants were also encouraged to discuss their endeavors with the study team to determine if STS could be utilized to enhance their investigations.

The information obtained from the screening of 1498's and inputs received from the presentations formed the body of the source material for the study. This information, coupled with information relating to the Shuttle, the Spacelab and other payload carriers, was used by TRW to perform the experiment assessments. The experiment specialists, who have performed many studies on Spacelab and Shuttle payload accommodation, then analyzed the selected experiments and produced the assessments contained in the study. (See Diagram Page 6)

Where possible, the Experiment/STS specialists contacted the DoD investigators to expand the information available so that the assessment would be more meaningful.



The items that were analyzed in preparing the assessments are enumerated below:

EXPERIMENT/APPLICATION DEFINITION

- MISSION REQUIREMENTS
  - Objectives
  - Orbit Requirements
  - Flight Dates and Duration
- PHYSICAL CHARACTERISTICS
  - Mission Equipment and Support Equipment
  - Weight, Volume, Size
  - Configuration, Deployed and Stowed
- CREW REQUIREMENTS
  - Number and Skill
  - Timeliness
- UTILITY SUPPORT REQUIREMENTS
  - Profile, Average, Peak
  - Electrical Power
  - Communication
  - Data Management
  - Environment Control
- CHECKOUT AND OPERATIONS
- GROUND SUPPORT REQUIREMENTS

STUDY ORGANIZATION

The study was performed under the direction of Major Carl Jund, the manager of the planning activity for Space Test Programs at SAMSO. He was assisted by Mr. Larry Weeks, The Aerospace Corporation, who provided technical support and guidance to TRW during the assessment phase.

The study was managed for TRW by Mr. Robert Elkins, with Mr. Thomas Hanes as deputy.

The specialists who performed the technical assessments are listed below, with a brief description of their qualifications.

In the event questions arise regarding the content of this report, please contact either Major Carl Jund at (213) 643-1121, or Mr. Larry Weeks at (213) 648-6236.

RESUMES

Dr. Nathaniel L. Sanders - Lead Scientist

Dr. Sanders' experience includes the management and planning relating to the performance of scientific experiments on spacecraft as well as participation as an experimenter. He has participated in numerous STS related studies. He has been with TRW for 17 years. His recent experience includes an assignment as the Assistant Project Manager for Experiment Accommodation on AMPS (Spacelab) Phase B Study.

Prior to that, he was the Assistant Project Manager for Experiment Integration, and Magnetic Control for Pioneers 6 through 11 (Jupiter).

Mr. Robert L. Hammel - Space Processing Specialist

Mr. Hammel has extensive experience in the Space Processing field. He has been the study manager for a Phase B study for NASA/Marshall Space Flight Center dealing with the definition of Space Processing payloads for early Spacelab flights.

Mr. Hammel was in charge of the TRW study for MSFC, "Concepts and Requirements for Materials Science Manufacturing in Space Payload Equipment Study," and the follow-on, "Space Processing Application (SPA) Payload Equipment Study." These studies concentrated on conceptual design of SPA payloads and engineering analysis of integration of these payloads into the Shuttle/Spacelab system.

Dr. Robert F. Doolittle - Space Physics Specialist

Dr. Doolittle has been involved in most aspects of space physics during his career. He has been on the staff at San Diego State University and has done research in the area of charged particle track detectors. He has been in charge of many company sponsored programs having wide application in the space physics field.

He was a staff scientist on HEAO working primarily on experiment integration. In this capacity Dr. Doolittle was thoroughly familiar with all electrical and mechanical interfaces of experiments, as well as their scientific objectives and characteristics.

Dr. Robert L. Wax - Ionospheric Physics Specialist

Dr. Wax has had extensive experience with the Space Shuttle system. Beginning in 1966, he worked on the second revision of the NASA Blue Book of Candidate Experiments for the Manned Orbiting Laboratory. He also did work on the final Blue Book version during 1970. In 1971-72, he participated at NOAA in the study of experiments for the Plasma Physics and Environmental Perturbation Laboratory (PPEPL) in Boulder under the chairmanships of J. R. McAfee and W. Bernstein. In 1973, he worked with the Martin Marietta Corporation in Denver to help produce the "Preliminary Concepts from Woods Hole Atmospheric and Space Physics," which involved the fitting of the 1973 Woods Hole recommendations into an AMPS-like configuration.

Mr. T. E. Hanes - Deputy Study Manager

Mr. Hanes joined TRW as a Special Consultant following retirement from NASA in 1975. His last assignment at NASA was as Director of Skylab Office administering closeout of the program after successful completion of the mission. He assisted the Skylab Program Manager, as one of six second-level assistants, from Skylab preliminary program definition through the entire life of the program. He was primarily responsible for integration of approximately 200 scientific, technological and applications experiments into the Skylab program. At TRW, Mr. Hanes has worked on the NASA Cost Reduction Alternative Study, the Atmospheric, Magnetospheric and Plasmas in Space (AMPS) payload, and as a specialist in procedural matters for all of our STS and Spacelab studies.

Dr. G. T. Inouye - Senior Scientist

Dr. Inouye has had extensive experience in the accommodation of instruments for space experiments. His academic background is in ionospheric physics and he has participated as magnetometer experimenter on spacecraft and rocket flights. His areas of special expertise are in magnetics and spacecraft charging. Most recently, he has worked on the AMPS (Shuttle) Payload Definition Study and on spacecraft charging problems relating to the DSCS II, FLTSATCOM, and TDRSS spacecraft programs.

MEDIUM LEVEL ASSESSMENTS

32 detailed assessments were prepared during the study; four examples are contained in this section.

The information presented in these assessments is general in some areas and covers concepts and integration and accommodation techniques rather than specific design and interface information.

A similar format was followed for each assessment to assure that the same criteria was applied to each experiment. The level of detail varied depending on the depth of existing information.

The outline for each assessment is:

1.0 EXPERIMENT IDENTIFICATION
2.0 REQUIREMENT BACKGROUND
3.0 EXPERIMENT APPROACH
4.0 ASSESSMENT FOR STS FLIGHT
  4.1 Experiment Considerations
  4.2 STP Integration Considerations
5.0 RECOMMENDATION(S) AND REMARK(S)

The medium level assessments were grouped by Laboratories, and agencies, essentially in the order that response sheets were received from interested investigators.

INDEX OF MEDIUM LEVEL ASSESSMENTS

Agency	Investigator(s)	Project Title	Response #
NRL	G. Carruthers	Far Ultraviolet Imaging and Photometry	2
NRL	S. H. Knowles	Radio Interferometer Satellite Link Experiment	4
NRL	J. D. Kurfess	Gamma-Ray Monitor for Space Shuttle	5
NRL	J. T. Schriempf	Laser Effects & Hardening of Satellite Materials & Components	6

INDEX OF MEDIUM LEVEL ASSESSMENTS (CONT'D)

Agency	Investigator(s)	Project Title	Response #
NRL	M. Shapiro, N. Seeman, F. O'Dell	Heavy Ions in Space	7
NRL	E.P. Szuszczewicz	Shuttle Effects on Plasmas in Space	8
Aerospace Corp.	Choh-Yi Ang	Crystal Growth & Homogenization of Semiconductor & Laser Materials	14
Aerospace Corp.	E. N. Borson	Effects of Space Environment on Spacecraft Material	15
Aerospace Corp. SAMSO	R. N. Cooper V. Slaboszewicz	Optical Countermeasures Demonstration (Satellite Survivability Program)	16
AFRPL	G. C. Sayles	Contamination from Satellite Propulsion Systems	22
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AFAPL	R. C. Brouns	Dynamic Power System	11
AFAPL	E. T. Mahefkey	Thermal Energy Storage Experiment	27
AFFDL	R. E. Harris	Mechanical Cryogenic Refrigerator Experiment	28
AFFDL	W. L. Haskin	Passive Cryogenic Radiator Experiment	29
AFFDL	D. A. Roselius	Adhesive/Structural Bonding in a Space Environment	30
AFML	W. L. Lehn	STS-LDEF Multiphase Materials Performance/ Contamination Experiment	31

INDEX OF MEDIUM LEVEL ASSESSMENTS (CONT'D)

Agency	Investigator(s)	Project Title	Response #
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AFGL	R. Filz	Passive Energetic Particle Detectors	33
AFGL	R. M. Nadile	Satellite Measurements of Infrared Airglow	34
AFGL	B. Schurin, S. D. Price and T. J. Murdock	Infrared Background Sensor	35
AFGL	P. Rothwell	Energetic Particles & Fields Experiment	36
AFGL	A. G. Rubin	1. MEV Alpha Particles Trapped in the Magnetosphere 2. Materials Effects on Spacecraft Charging	37
AFGL	R. Sagalyn, F. Rich	Controlled Artificial Depletion of the Ionosphere	38
AFGL	M. Smiddy	Sheath and Wake Studies	40
AFGL	P.J.L. Wildman	Neutral Atmosphere/Plasma Interaction at Low Latitude	41
AFGL	R. E. Huffman	Horizon Ultraviolet Experiment	44
AFGL	K. Champion, D. Bedo	Atmospheric Topside Laser Sounder	45
AFGL	A. T. Stair	Enhanced Infrared Emissions	65
RADC	T. Elkins, G. Sales	Ducted Ionospheric Radio Propagation Experiment	42
RADC	C. S. Sahagian	Growth of Cinnabar (α-HgS) in a Low Gravity Environment	46
Mitre Corp.	B. E. White	Bubble Memory Experiment	43

CONTAMINATION FROM SATELLITE PROPULSION SYSTEMS

1.0 EXPERIMENT IDENTIFICATION

Gerald C. Sayles, Principal Investigator
AF Rocket Propulsion Laboratory, Code XP
Edwards AFB, CA

2.0 REQUIREMENT BACKGROUND

Response to STS Utilization Presentation (Response Sheet #22)

Identifying number and title: PE 62302F, Proj. 3058, Rocket Propulsion Technology

Supplementary information obtained from Don Young and Lou Molinari, Propulsion System Division, JPL, Pasadena, CA. (concurrent NASA-sponsored flight test program definition study, Oct. 1977- Sept. 1978)

3.0 EXPERIMENT APPROACH

3.1 Objective

The objective of this test is to perform quantitative measurements of rocket exhaust plumes under vacuum conditions in earth orbit and to characterize contamination effects of critical satellite components in close proximity of the rocket, such as solar cells, optical surfaces, thermal coatings, etc.

The principal concern is to determine whether existing analytical models of rocket exhaust flow and contamination effects are realistic and quantitatively accurate.

3.2 Experiment Description

A test facility installed in the Shuttle Orbiter cargo bay will be used to operate various propulsion system specimens in low earth orbit and to map the exhaust plume, using an array of appropriate detectors and measuring equipment placed at various locations relative to the exhaust nozzle and the main flow of exhaust products. Tests will be performed in short, continuous or pulsed operating cycles depending on thruster type.

Current plans project a series of six test missions each devoted to a different propulsion system test specimen, as listed below in the order of the most likely test flight sequence:

1. 25-lb_f monopropellant hydrazine thruster (MSFC)
2. 800-lb_f liquid bipropellant thruster using monomethyl hydrazine and nitrogen tetroxide as propellants, similar to the Shuttle primary RCS thruster (JPL)
3. 8-cm mercury ion thruster (LeRC)

4. 1000-lb_f solid propellant rocket (JPL)
5. 30-cm mercury ion thruster (LeRC)
6. 25 lb_f GO_2/GH_2 thruster (LeRC)

Dimensions, weights, propellant mass, plume characteristics, experiment power requirements, heat dissipation and other basic data of these thrusters require further definition for a more detailed assessment.

Detectors and measuring equipment to be used will depend on the thruster type being tested but will probably include the following:

- mass spectrometers
- surface collectors
- quartz crystal microbalance
- Langmuir probe and Faraday cups (to be used in ion engine tests)
- solar cell specimens

Thrust level measurements may also be included, e.g., in the tests of high-thrust propulsion systems.

To avoid undesirable Orbiter attitude perturbations during the firing of these rockets, alignment of the thrust axis with the Orbiter center-of-mass is required, since concurrent firing of the Orbiter's RCS thrusters for the purpose of nulling perturbing moments will not be permitted. This restriction is necessary to preclude possible exhaust interference with contamination measurements of the test specimen.

Before initiating the test series the experiment platform will be raised from the stowed position in the cargo bay to a height of 2 to 6 ft (depending on the thruster type) above the door mold line and locked in place. This is necessary in order to (a) eliminate any influence on the rocket contamination measurements due to traces of other contaminants surrounding the Orbiter hull in a thin layer, (b) to reduce the effect of cargo bay surfaces on the rocket exhaust flow field, and (c) to avoid interference with, and contamination of other payloads carried by the Orbiter.

Details of the experiment design, the platform dimensions and layout, the test equipment and the plume mapping procedure remain to be defined. A test planning and design study intended to provide such data will be initiated by JPL in October 1977 under NASA/OAST funding. Several man-years of study effort are projected.

3.3 Orbit

The principal requirement is to perform the test at altitudes above the sensible atmosphere. This means that, in general, any Orbiter flight of opportunity with sufficient spare payload weight and cargo bay space could be used to accommodate the propulsion tests. Orbit characteristics are generally of no concern.

3.4 Test Data Acquisition

Each test will be performed in a preprogrammed sequence, with the Orbiter crew only performing the tasks of raising the test platform to the required position above the cargo bay, turning the propulsion system on and off and monitoring the test while in progress. Test data will be recorded onboard the Orbiter and returned to the ground for post-flight analysis. A requirement for on-orbit checkout and trouble-shooting by the Orbiter crew of the specialized test equipment and the propulsion system specimen is not envisioned. Except for the required power source, test data recording and remote control circuits and displays no major electrical interface with the Orbiter system will be required. The experiment is largely self-contained.

4.0 ASSESSMENT FOR STS FLIGHT

The Shuttle Orbiter provides a convenient test bed for this experiment, facilitating realistic rocket exhaust measurements under vacuum conditions, and easily accommodating hundreds of pounds of test equipment and the propulsion test specimen at a low transportation cost. By the intended preprogrammed, automatic sequencing of thruster firing and measurement procedures this nearly self-contained experiment only requires a minimum of crew involvement. Principal areas of concern are:

- Provision of safeguards against possible hazards inherent in carrying appreciable amounts of propellants in the cargo bay and firing propulsion systems in close proximity to Orbiter structures and other payload elements.

- Availability of adequate power (3 to 4 KW) for operating the large (30 cm) ion thruster over an extended period.

- Dissipation of waste heat, e.g., about 1 KW prior to and during operation of the large ion thruster. This may be of critical concern because of the tight thermal control required for the quartz crystal microbalance being used in the test.

- Maintenance of the Orbiter's attitude when operating large 800 to 1000 lb rockets if the thrust axis is not accurately aligned with the center of mass. Two-axis gimballing of these rockets may be required to minimize perturbing moments.

4.1 Experiment Considerations

4.1.1 Safety

Safeguards are necessary to guard against inadvertant firing of the test rockets before the experiment platform has been erected to the operating position; against exposure of sensitive payloads to the test rocket exhaust plume; against the possibility of spilling corrosive, combustible, and toxic propellants into the cargo bay and against heat from the large chemical propulsion thrusters or the 3 KW ion engine affecting sensitive equipment in the cargo bay. Some of these hazards

can be reduced to an acceptable level by appropriate design of the test facility, by interlock provisions, redundant safety features and thruster enclosures, and by safe test operating procedures through adequate crew training. Monitoring displays and caution/warning indicators at crew stations also are essential.

4.1.2 <u>Monitoring of Background Contamination</u>

The possible effect of contaminants in the Orbiter environment on sensitive measurements of the thruster exhaust plume can be determined by scanning the detectors through the region surrounding the test specimen before initiating the firing test. Any noticeable background levels can then be subtracted from the contaminant flow measured during the test operation.

Time variations of contaminant distribution should also be monitored to detect such effects as decay of exhaust concentrations after Orbiter RCS system firings.

4.1.3 <u>Preprogrammed vs. Adaptive Test Program</u>

As currently envisioned by test planners, the thruster firing and plume mapping operations will be conducted in a pre-programmed sequence. Different sequences will be designed for the different propulsion systems to be tested. This approach is simple and reliable, requires little or no participation by the Orbiter crew, and minimizes communication with investigators on the ground. All test results will be recorded onboard the Orbiter for post-flight processing and analysis.

This approach, favored because of its simplicity and low cost implications, however, does not permit the use of adaptive techniques where the experimental sequence can be influenced by the outcome of preceding steps and the capacity of the human operator for improvisation, factors generally considered a principal asset when planning Shuttle-borne experiments.

Further study of alternate approaches is recommended to determine:

- Whether a fully preprogrammed test meets all safety requirements.
- How much cost and complexity is saved by adopting a preprogrammed procedure.
- Whether the cost of repeating an unsuccessful or incomplete test on another Shuttle flight of opportunity is sufficiently small to justify the economical but more failure-prone pre-programming approach.
- How long a waiting period, on the average, is to be expected between Shuttle flights of opportunity based on current traffic models.

4.2 STS Integration Considerations

4.2.1 Multi-Purpose vs. Application-Tailored Test Platforms

The test program includes propulsion systems of great diversity and thrust level ranging from a 1-millipound (8cm) ion thruster to a 1000-pound solid rocket. Dimensions and weights of the thruster specimens, complexity of the system components and subtlety of plume mapping techniques similarly vary over a wide range.

The cost trade-off between a single multi-purpose test platform for this diversity of test objects and developing test platforms tailored to different classes of test objects requires further study.

Test equipment commonality includes items such as:

- Platform and deployment mechanism
- 2-axis gimbal mount for thrust vectoring of large rockets, including control electronics.
- Scanning boom(s) for plume mapping instruments and detectors (not necessarily required).
- Data handling interface equipment
- Test sequence programmer

Support Equipment tailored to individual test items will include the following:

- Mounting and support brackets
- Power Supplies
- Thermal control equipment, shields and radiators
- Data acquisition and data handling modules
- Propulsion system control circuits

4.2.2 Conceptual Layout

Because of the very preliminary status of the test program definition, the layout of the test facility can be presented only in rough outline. However, from the foregoing discussion of test objectives and procedures the following general design requirements and preliminary configuration aspects are apparent:

(1) The support platform must be designed for stowage on a standard test rack and for deployment to a height of about 5 to 8 ft. above the stowed position. A scissors-type deployment linkage is a promising candidate. This deployment mechanism may be required to permit locking the platform at several discrete positions above the stowed position.

(2) The platform must be able to accommodate the largest rockets contemplated in the program, i.e., the 1000 lb_f solid motor with a typical length of 30 to 40 inches and a variety of propellant storage and feed systems.

(3) A two-axis gimbal mount may be required in some instances to align the thrust vector with the Orbiter's center of mass. However, alignment accuracy is modest (probably $\pm$ 1 degree).

(4) The preferred location of the platform center in X-direction is close to the Orbiter C.M. (typically, within $\pm$ 5 ft. of the C.M.) at least for the high-thrust propulsion systems in the test series. This permits thrust vector orientation within about 30 degrees from the Z-axis and, thus, minimizes plume impingement on Orbiter structures or on objects in the cargo bay.

(5) An articulated boom may be required to scan contamination sensors along and across the thruster exhaust plume. The diversity of thruster sizes and exhaust plume characteristics calls for large variations of scan motions and coverage range which must be accommodated by the boom design. These booms must be safely stowed prior to platform deployment. (Note: According to information received from JPL's Propulsion System Division, the maneuverable scanning boom may be omitted to reduce cost and complexity of the experiment.)

(6) As a safety provision, the entire deployable experiment platform must be jettisonable if the retractor mechanism fails to operate. The deployable scanning boom also must have a jettison provision.

Figure 4.2-1 shows a conceptual layout of the experiment platform in stowed and deployed positions. The 800 lb bipropellant rocket and propellant tanks (Experiment 2) are shown as a sample propulsion specimen.

In this layout it is assumed that some other cargo occupies the rear portion of the Orbiter's cargo bay and extends forward just beyond the center of mass (assumed at Station 1150). As illustrated, the propulsion test platform is placed between cargo bay stations [illegible] and 1070 forward of the center of mass. Thus the thruster must be installed at a forward tilt angle (approximately 30 degrees) from the Z-axis to achieve near-zero thrust vector offset from the C.M. A two-axis thruster gimbal mount is shown in the drawing which will be used for in-flight thrust axis alignment if necessary. (Further analysis is required for a specific platform installtion and for specifics of the Orbiter mission to determine whether this added complexity might not be avoidable).

A two-axis gimballed test equipment deployment boom of the STEM type, attached on the starboard side of the platform (to avoid interference with the Remote Manipulator Arm) is provided for mapping the exhaust contamination flow field in three dimensions to distances of 8 to 10 ft.

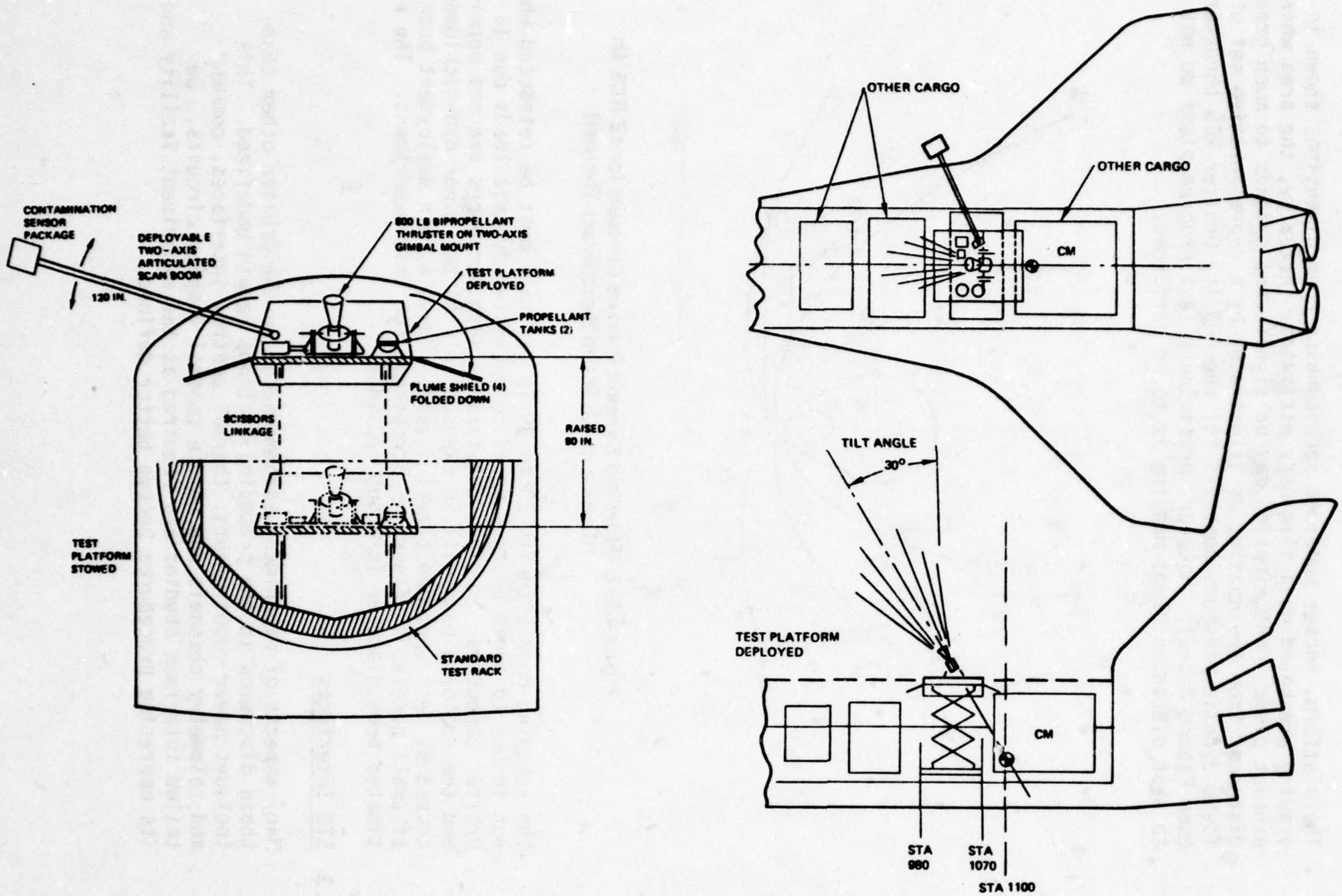

Figure 4.2-1. Conceptual Layout of Propulsion Test Platform (Example 800 lb Bipropellant Thruster Experiment)

The platform, rocket specimen and scanning boom dimensions shown in the drawing are based on preliminary estimates. Actually, the area where exhaust plume contamination may be significant extends to much greater distances from the nozzle, as illustrated by a representative set of flow field dynamic pressure contours for the 800 lb_f Orbiter RCS thrusters (see Figure 4.2-2). However, preliminary test program plans do not specify to what distances plume mapping is to be performed.

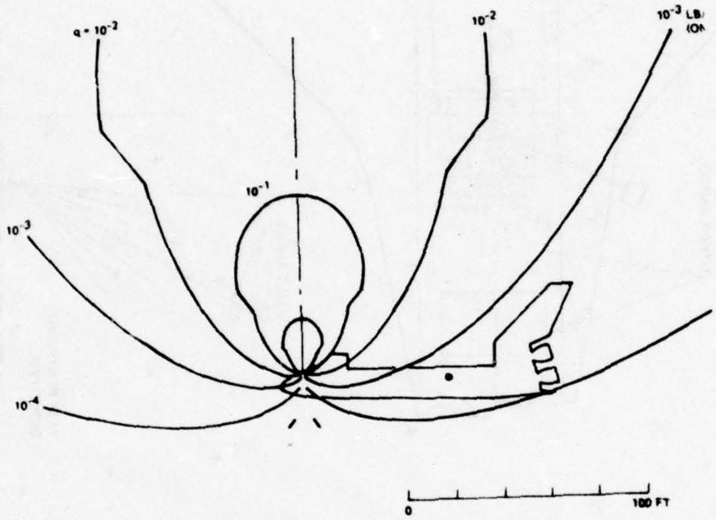

Figure 4.2-2. Flowfield Dynamic Pressure Contours for +Z RCS Jet (Representative 800 lb Bipropellant Thruster)

The scanning boom with its 20 to 30 lb tip mass must be retracted when not in use to avoid being exposed to excessive dynamic loads due to Orbiter maneuvers. During test firings such maneuvers are not permitted, and the deployed boom will be exposed only to the minor dynamic loads caused by test specimen thrust itself. Thus, a thin deployment boom of small bending stiffness is acceptable for this experiment. The estimated boom diameter is about 1/2 inch.

4.2.3 STS Interfaces

Many aspects of experiment accommodation on the Orbiter other than those discussed in the preceding sections remain undefined. This includes power requirements, thermal control interfaces, command and telemetry channels and remote control display circuits. Detailed interface studies are required as the experiment facility and its operating procedures become better defined.

4.2.4 Cost Considerations

Factors that aid in conducting this experiment at low cost have been discussed in the context of test facility design and operation. In summary, the following cost-saving considerations apply:

- Reuse of the facility for different propulsion specimens multi-purpose design reduces equipment and pre-flight preparation cost.
- Minimum demand on crew participation saves training cost and avoids interference with other crew duties.
- Short total operating time allows flexibility of scheduling during the mission and avoids interference with other flight objectives.
- Onboard storage of test data minimizes ground communication requirements.
- The experiment can take advantage of Shuttle flights of opportunity since mission characteristics are of little concern. This tends to reduce transportation cost.
- Many components of the test facility can be adapted from other flight programs and from propulsion test facilities on the ground.
- Weight and space requirements are reasonably small (estimated weight about 1000 lb, installation length about 5 ft on portion of test rack) to permit inexpensive STS transportation ($300 K to 400 K).

5.0 RECOMMENDATIONS AND REMARKS

Since information on this experiment series was too sketchy for a detailed assessment, it is recommended as a next step (even before the forthcoming experiment definition study by JPL is completed) that principal data on thruster dimensions, weights, propellant mass, plume characteristics, experiment power requirements, heat dissaipation, etc. be compiled as soon as possible and evaluated from an STS interface definition and experiment integration standpoint. This will aid in making preliminary estimates on STS integration, transportation and experiment operation costs.

Cost benefit aspects of the multi-purpose experiment facility design vs. tailored facility designs require further study as the diversity of test equipment to be used are better defined. Secondly, cost benefit tradeoffs between fully preprogrammed and adaptive test procedures are important as they affect crew functions and data handling and ground-to-Orbiter communication requirements.

HORIZON ULTRAVIOLET EXPERIMENT

1.0 Source

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(617) 861-3043

2.0 REQUIREMENTS BACKGROUND

Response to STS Utilization Presentation (No. 44)

Identifying Numbers: FY 77, Work Unit 66880701
FY 78, Work Unit 66901702, UV Horizon Measurements

Form 1721 is in preparation

3.0 EXPERIMENT APPROACH

3.1 Objectives

This experiment is to provide detailed quantitative data on brightness of the earth's atmosphere, and in particular, that of the earth's limb, at ultraviolet wavelengths ranging from 500 to 4000°A. This information is needed to aid in the development of UV horizon sensors and of sensors applicable to missile surveillance and tracking. Lack of sufficient UV atmospheric and earth limb profile data is hampering progress toward development of such sensors at present.

Data from the proposed experiment will permit evaluation of the potential of UV horizon sensors in comparison with existing IR horizon sensors. In addition, sensors with improved characteristics, including greater accuracy, reduced complexity and cost, and lower susceptibility to geophysical variations, cloud interference, etc., are needed for systems engaged in missile surveillance and tracking, communications, navigation, and in most earth-oriented observations.

The proposed limb observation experiment will provide the needed data on UV radiance along slant paths. This is the background against which missile exhaust plumes are to be detected.

3.2 Background

Several rocket and satellite flight programs are currently being planned by the Air Force Geophysics Laboratory to perform related UV atmospheric measurements but on a less comprehensive scale. In these measurements,

the sensors will make observations primarily in the nadir direction. The flight programs include the following:

1) VUV Backgrounds, CRL-246, SIP Mission S77-2. This experiment is being integrated into a pallet payload at the present time under the guidance of the Space Test Program Office at SAMSO. Spectral and spatial data will be obtained in the nadir direction. Some limb scans may be possible at the conclusion of the flight, depending on resources, but the detailed, global coverage needed will not be obtained. Data are expected during CY 1978.

2) Multispectral Measurements Program (MSMP). This program will obtain missile exhaust plume intensities in a wide wavelength region from the infrared through the ultraviolet. It is associated with SAMSO (SZ). The UV sensors will provide spatial and spectral target data that will be used with background data in order to develop the most suitable applications for ultraviolet missile detection. The program involves a series of Aries rocket launches carrying both a separable target engine and a sensor module. Flights are planned over the next several years with the initial launch during 1977.

This proposed Shuttle-based experiment series will implement the earlier programs by systematically mapping the brightness of the near-earth atmosphere as a function of pointing direction, or altitude, and ultimately provide global coverage. Although the emphasis is on limb profile measurements, a sufficient number of scans from nadir to horizon will be conducted for correlation with results from the earlier experiment series.

3.3 Experiment Equipment and Procedure

3.3.1 Equipment

The instrumentation is composed of six 3x4x12 inch Faste-Ebert UV spectrometers that are independently set to a wavelength band of interest. Together, they cover the wave length range from 500 to 4000°A. Motor driven mirrors are used to scan the incident ultraviolet light across variable-geometry diffraction gratings. The instruments' clear field of view is 0.1 to 0.5 degrees. The external configuration of the spectrometer is illustrated in Figure 3.1. A gimballed mounting platform capable of pointing the spectrometers at various points of the horizon and of scanning the limb is to be provided as flight support equipment. This gimballed platform also isolates the precision pointing spectrometer package from Orbiter altitude changes.

The required pointing accuracy is between 0.1 and 1 degree and the required pointing stability 0.1 degrees per 5 millisec (the exposure duration per measurement). These accuracy requirements are preliminary and can possibly be alleviated. Knowledge of the pointing direction is more important than exact control.

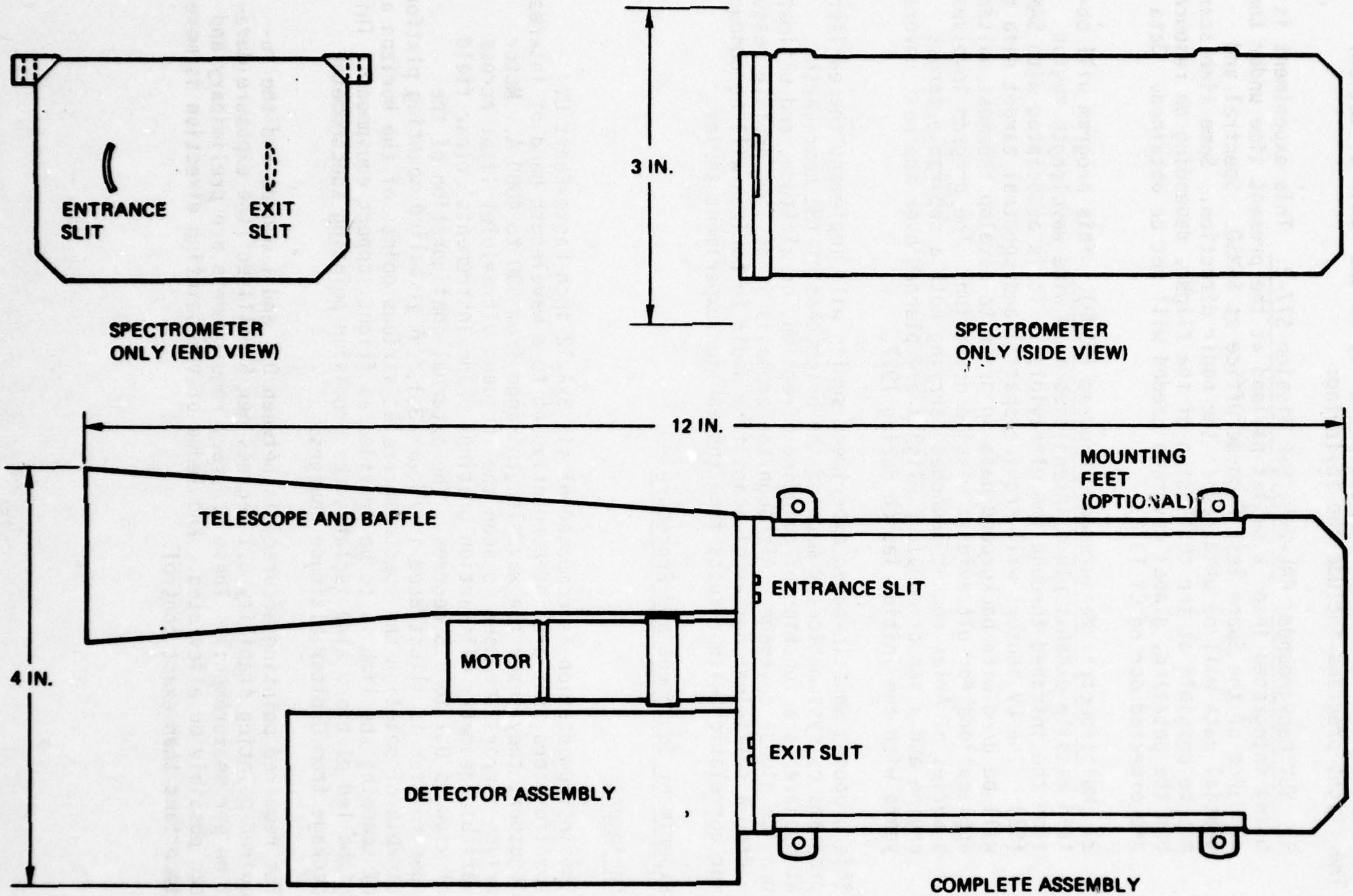

Figure 3-1. Configuration of Horizon UV Spectrometer (Preliminary Sketch)

Platform gimbal angles relative to Orbiter coordinates as well as the Orbiter orientation angles must be recorded at all times during the measurements to permit transformation to earth-based coordinates for post-flight analysis of limb scan data. To simplify the communication interface with the ground, it is proposed that all UV data acquired by the instruments be stored on-board for processing and evaluation upon return to ground.

The observations are easier to interpret if the Shuttle and/or the gimbal axis orientations are such that the limb scan direction is normal to the horizon, although results from other scan orientations are acceptable.

To accommodate the experiment pointing requirements including observations at the horizon, between horizon and nadir and occasional tracking of rocket firing events, the Orbiter must maintain a nominal orientation in which the cargo bay is pointed downward. Limited excursions from this attitude are acceptable if they don't interfere with experiment pointing requirements.

UV scan requirements are compatible with infrared limb scanning experiments and earth resources observations, and the gimballed pointing platform to be used for the UV sensors can probably be shared with the IR limb sensors in the interest of cost economy.

Power requirements for the six UV spectrometers and electronics is estimated as averaging 12 W. Data handling requirements include six 16 bit words per channel with a 5-millisec counting period. Data acquisition is on a 25 percent duty cycle when the equipment is operating, reflecting observations only at or near the limb. Since real-time transmittal to ground is not a requirement, the data flow can be stored on tape even for a sortie operation of several weeks. Analog data from 8 to 12 monitors are estimated to be generated at a rate of 1 cps or less. Six commands are required for power on and off switching and six commands for wavelength steps (one each per UV channel).

The instruments are designed to operate in a preferred temperature range of 15 to 25°C. A wider range (0 to 35°C) is acceptable. However, extreme temperatures of -20°C and 100°C should not be exceeded to preclude damage. If the heat pulse following Orbiter landing is likely to be more severe, additional thermal protection should be provided.

3.3.2 Experiment Procedure

Operation of the experiment can be pre-programmed for automatic limb scans at selected points of the horizon over some time intervals during the nominal 7-day mission of the Shuttle Orbiter. Occasional scans toward nadir are required to correlate the measurements with those of the earlier flight programs. Each limb scan is estimated to be completed in one to several minutes.

In addition to horizon scanning, the mission plan will define opportunities for viewing rocket firings at launch sites such as ETR, WTR and Wallops Island, if the orbiter pass is within observation distance. The timing of the mission and the rocket launch schedule require careful advance consideration as well as confirmation and program adjustment while the mission is in progress. Although trajectory data of the target rocket and relative position data between the Orbiter and the target will be provided by mission control to the Orbiter on a real-time basis to control instrument pointing, it is anticipated that visual tracking and manual pointing control override may be necessary by one of the crew members to assure successful observation of the event.

Other than this specific task, participation of the crew in the conduct of the UV experiments is minimal. These crew activities are restricted to:

- Initially deploying the pointing platform from the stowed condition (see below) when the Orbiter is ready for orbital operations.
- Readying the experiment for measurement initiation which is commanded from the ground.
- Monitoring the status of the experiments.
- Effecting secure retraction of the platform prior to closing the cargo bay in preparation for reentry.

3.4 Shuttle Orbits

The program requires acquisition of UV atmospheric data at all latitudes. Initial flights launched from ETR will permit coverage of low and intermediate latitudes only. Shuttle flights launched off WTR will permit measurements in polar orbit at a later time. This will extend geographical coverage to higher latitudes and permit observation of auroral UV phenomena, considered important to this program. Ultimately, complete global coverage of UV atmospheric phenomena is desired.

Since orbital altitudes are not critical to the experiment (altitudes from 100 to 400 n.m. are acceptable), there will be many flight opportunities. However, with increasing altitude the slant range to the horizon increases rapidly, and consequently, resolution and accuracy of the UV limb measurements decrease. On the other hand, higher orbital altitudes will provide more frequent opportunities for rocket firing observation (see below).

3.5 Program Evolution

Work toward UV horizon sensors will involve a series of missions. Initially, it is necessary to acquire the needed limb profiles to evaluate the suitability of the UV limb for this purpose. Global coverage is required which will require a number of flights. In addition, various developmental ideas will be evaluated in space.

Operational, or near-operational, sensors may use detectors that are different from those used to gather the limb data. Alternate techniques for using the UV limb and alternate sensor designs, multicolor systems and onboard processing approaches require in-flight testing in subsequent phases. AFGL therefore foresees a continuing evolutionary UV experiment program in the development of operational sensors for use on spacecraft.

4.0 ASSESSMENT FOR STS FLIGHT

The horizon UV experiment will provide data that are essential to the development of UV detectors for horizon sensing and for missile surveillance and tracking. Such sensors will be used to complement the capabilities of existing IR sensors. To cover the spectral range from near-UV through VUV and XUV, the measurements must be conducted from above the earth atmosphere.

Utilization of the Shuttle Orbiter for this experiment is primarily a matter of cost effectiveness in view of the following considerations:

a) Repeated flights are required to obtain the necessary atmospheric UV data base and to support sensor technology evolution.

b) Measuring equipment and flight support equipment can be reused in successive flights.

c) Some of this equipment can be shared with similar IR experiments (e.g., the pointing platform) being carried in the same mission.

d) The Shuttle Orbiter provides most of the engineering support and housekeeping functions required by the experiment.

e) The experiment has modest weight, volume and power requirements (except for the pointing platform) and can be accommodated on Shuttle flights that are shared by several other users.

The experiment is largely self-contained and can be conducted automatically in a pre-programmed sequence. Atmospheric and target observation data, acquired by the experiment, can be recorded and stored for post-flight analysis, along with data on relevant Shuttle operating conditions, e.g., orientation angles and orbit positions.

Experiment support onboard the Orbiter requires a precision pointing platform with two (or preferably three) gimbal drives to provide sufficient line-of-sight pointing accuracy and to decouple the sensors from Orbiter rotations. Otherwise, the electrical and mechanical interfaces with the Orbiter system are of modest complexity.

Crew tasks and ground communication requirements are minimal except during observation of rocket firings. The objective of rocket plume observations requires careful coordination with launch site activities prior to and during the mission and will constrain Orbiter mission timing and mission profile selection.

Orbit characteristics required for the experiment are compatible with many other Shuttle sortie missions. This facilitates experiment accommodation. Also, the nominal Orbiter flight attitude with the cargo bay pointing downward is compatible with other Shuttle earth observation and atmospheric research objectives, especially since limited pitch and roll excursions from the nominal orientation do not interfere with the experiment and are acceptable.

4.1 Experiment Considerations

4.1.1 Scan Patterns

Limb scan patterns that may be used in the experiment include:

- A squarewave pattern with measurements taken during the upward and/or downward strokes.
- Sinusoidal or triangular wave patterns.
- A sawtooth pattern scanning in nearly vertical direction downward.

The sawtooth pattern seems best suited for purposes of this experiment since it scans nearly normal to the horizon and always in the same direction.

Azimuth sweeps may be conducted around the entire horizon or within some limited azimuth angle. The circular azimuth sweep tends to produce overlapping coverage in successive orbital passes. For example, with 200 n.m. orbital altitude and 50 n.m. horizon altitude, the horizon radius is 1035 n.m. The distance between adjacent ground tracks at 30 degree orbit inclination is only 675 n.m. The overlap beyond adjacent ground tracks, therefore, is 360 n.m. A limited azimuth sweep on one side of the Orbiter, e.g., between 30 and 150 degrees from the velocity vector, avoids this overlap. It also precludes field-of-view obstruction and reflected light interference by the Orbiter's front and tail structures.

4.1.2 Day and Night Observations

Both day and night observations of the atmosphere are desirable. Fluorescence and sunlight scattering effects are observable only in daylight, but sun interference at angles up to 90 degrees from the instrument center line must be avoided. This implies some azimuth restrictions during daylight observation and near the terminator. Eclipse durations depend on orbital altitude, inclination, equator crossing times and season. For low inclination orbits, the eclipse duration is typically one-third of the orbit period. Thus, the available observation times in sunlight and eclipse tend to match observational priorities indicated by the experimenter.

4.1.3 Rocket Plume Observation

Careful advance and in-flight coordination with rocket launch schedules is required in order to make rocket plume observation from the Orbiter possible. A first such observation was conducted successfully during the SKYLAB program during a passage of WTR although the observatory's 51-degree orbital inclination was not optimal for this purpose. Crew participation in target acquisition and

tracking as well as instrument pointing proved essential in conducting that experiment.

"Observation windows" occur when one of several Orbiter passes of the launch site fall within the daily launch window of a missile or satellite launch event. With a four-hour launch window and several successive orbiter passages near the launch site at about 90-minute intervals, as many as three observation windows may occur under favorable conditions, as illustrated in Figure 4.1-1.

Figure 4.1-2 shows successive ground tracks of a 30-degree inclined orbit in the vicinity of ETR. The tight ground track pattern that forms near the maximum latitude permits five or more successive target observation opportunities. Three concentric circles indicate launch site distance of the Orbiter passes, with the largest circle of 1200 n.m. radius representing a typical horizon distance.

Target observability actually depends on many factors including the UV instrument detection range and rocket plume intensity, the amount of background interference, and on relative Orbiter, target and sun positions. Because of the geometrically sensitive nature of the encounter, detailed analysis of target observability is necessary in each case. However, it is apparent that orbit inclinations between 30 and 35 degrees are more favorable than higher or lower ones because of latitude compatibility with different U.S. launch sites (ETR, WTR and Wallops Island).

4.2 STS Integration Considerations

The UV sensors are sufficiently well developed and compatible with the Orbiter so that integration should cause no major problems. Since the experiment is a continuation of rocket and satellite flight programs, there should be no need for extensive testing or simulation. Assuming that the sensors be mounted on a pointing system such SIPS (see below), which will be available as part of the Spacelab system, there should be no problem integrating the instruments with the flight support system. The experiment can therefore be accommodated early in the STS program on a "space-available" basis.

4.2.1 Configuration Concept

Use of the Small Instrument Pointing System (SIPS), is suggested as a support platform for the package of six UV spectrometers used in this experiment (See Figure 4.2). The SIPS, being developed under NASA/GSFC direction for the Spacelab program, consists of a deployment/retraction pedestal and a pointing section which includes an azimuth rotation drive and a pair of instrument canisters supported and gimballed separately in elevation. Each canister can be rotated independently inside its elevation yoke over a small range of angles. An optional roll gimbal assembly can be added to support the instruments inside the instrument canister. The angular freedom of these gimbal drives is as follows:

Azimuth ±200°
Elevation ±120°
Right Left (in the elevation yoke) ±10°
Roll (about instrument line of sight) ±125°

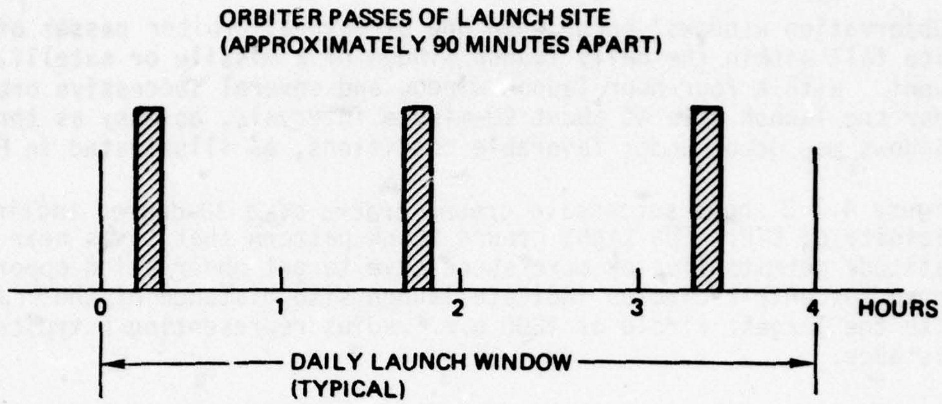

Figure 4.1-1. Observation Windows of Rocket Firing

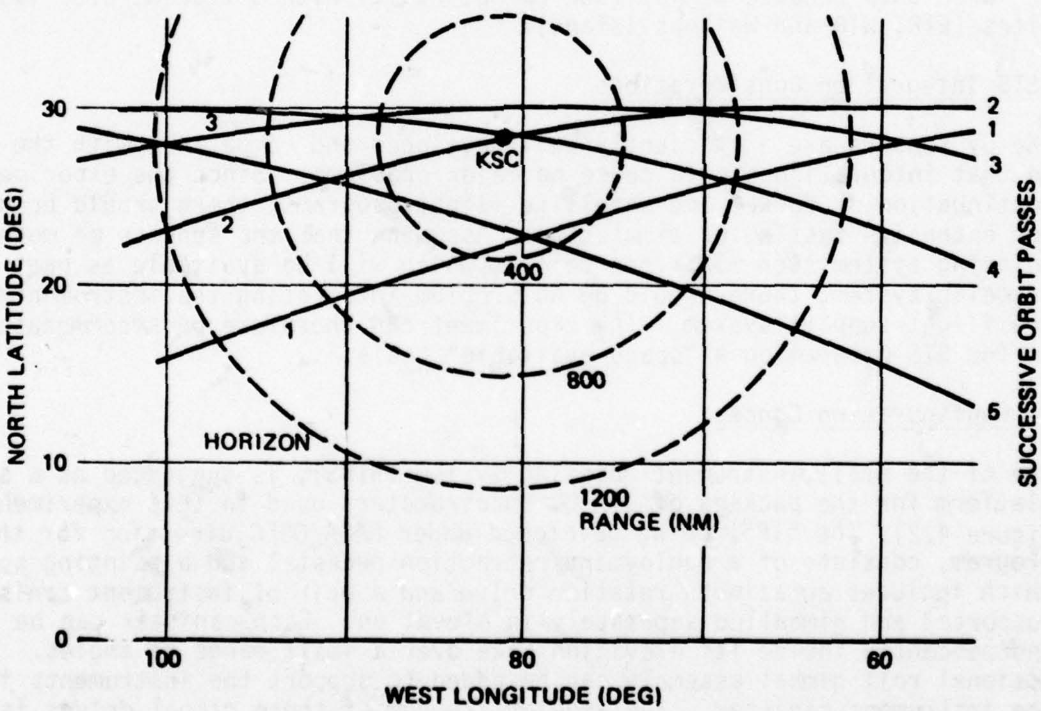

Figure 4.1-2. Successive Orbiter Passes in Vicinity of ETR

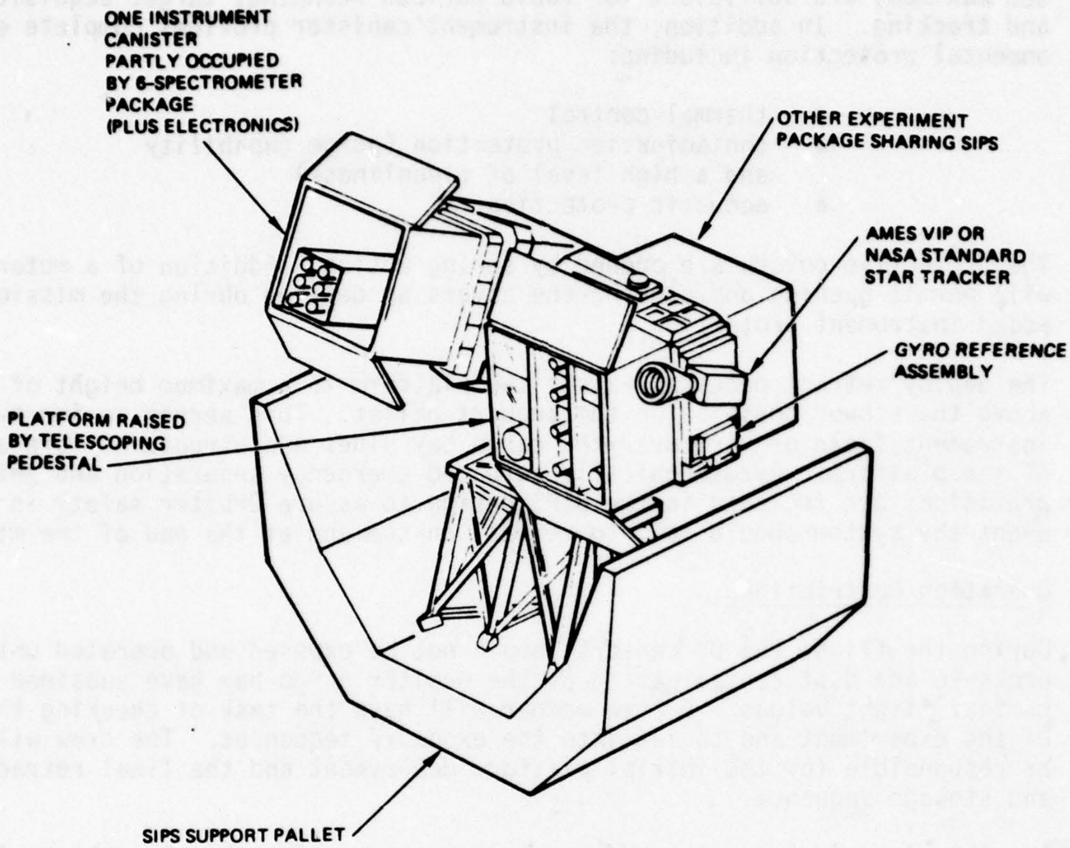

Figure 4.2. Installation of UV Experiment on SIPS

The use of the optional roll gimbal is recommended to maintain the spectrometer slit parallel to the horizon under varying Orbiter pitch or roll orientation. The inside dimensions of the canister (40 x 40 in cross-section) and the roll gimbal (34 inches diameter) provide ample space to accommodate the six spectrometers (16 x 16 inches combined) and associated electronics packages (dimensions 5 x 5 x 6 inches).

The second SIPS instrument canister and its gimbal support structure are not required and can be omitted. However, they may be utilized for another optical scan experiment with similar pointing requirements, thereby sharing the SIPS platform cost and weight.

The platform, designed for astronomical instrument pointing, provides pointing accuracies and stability exceeding those specified for the UV experiment. Pointing sensors suitable for the accuracy requirements of the experiment can be selected from a "stockpile" of standard units. Slewing rates (2 degrees per

sec maximum) are sufficient for rapid horizon scanning, target acquisition and tracking. In addition, the instrument canister provides complete environmental protection including:

- thermal control
- contamination protection (purge capability and a high level of cleanliness)
- acoustic protection

The protective covers are opened by spring action. Addition of a motor drive will permit opening and closing the covers as desired during the mission for added instrument protection.

The deploy/retract pedestal raises the platform to a maximum height of 4.3 ft. above the stowed position on the support pallet. This serves to improve the instrument field of view over the cargo bay sides and structures fore and aft of the platform. Pyrotechnically actuated emergency separation and jettison provisions are included in the SIPS design to assure Orbiter safety in the event the system should fail to retract on command at the end of the mission.

4.2.2 Operation Restrictions

During the flight the UV sensors should not be exposed and operated until the pressure and dust contamination of the orbiter cargo bay have subsided to their nominal flight values. A crew member will have the task of checking the status of the experiment and to initiate the exposure sequences. The crew will also be responsible for the initial platform deployment and the final retraction and stowage sequence.

Possible interference with UV atmospheric observations by the exhaust from the Orbiter's RCS thrusters must be avoided. Contamination of optical surfaces by rocket exhaust particles is probably of no concern during firing of the small (25 lb) vernier thrusters but could be more significant during operation of the 900 lb primary thrusters. During these events, it may be necessary to close the protective covers on the SIPS instrument canisters. Instrument protection during any major orbital maneuvers in which the large 6000 lb OMS engines are fired, is a primary concern. However, such maneuvers probably would be performed with the cargo bay doors closed and thus would interrupt any other orbital experiment as well.

4.2.3 Preflight Preparations

Principal preflight preparations include:

- Evacuation and sealing of instrument.
- Optical alignment of the sensor package.
- Checkout.
- UV sensitivity checks and calibration.
- Recalibration between flights and recleaning, if necessary.

The design of the SIPS platform and instrument support canisters facilitates late access during ground integration and delivery of a fully aligned, checked out and sealed instrument package.

4.2.4 Cost Considerations

Low cost of STS services for this experiment can be realized because of its small instrument weight (estimated as 40 lb. including electronics) and size, because of its compatibility with mission profiles and orbit characteristics common to other earth observation missions, and because of modest demands made on crew activities. Special mission timing and coordination requirements with rocket launch schedules do not necessarily increase the STS service cost but primarily restrict the number of flight opportunities that may be utilized.

The cost of using the SIPS can be greatly reduced by sharing this platform with other experiments, perhaps even the same instrument canister since the spectrometer package occupies only one-third to one-fourth of the canister viewing area. Since the total required observation time is probably less than one day, time-shared SIPS operations during a seven-day mission will be acceptable.

5.0 RECOMMENDATIONS AND REMARKS

The experiment is compatible with the STS and can take advantage of the frequent flight opportunities offered for earth and atmospheric observation payloads. An available pointing platform such as SIPS can accommodate the UV instruments readily, having the required pointing accuracy and stability as well as environmental protection provisions. Sharing of the SIPS with other experiments is feasible and will considerably reduce cost.

An area requiring more detailed analysis is the requirement for, and feasibility of, coordination with rocket launch schedules, the availability of "observation windows," and the degree of crew involvement in accomplishing rocket plume observation.

STS - LDEF MULTIPHASE MATERIALS PERFORMANCE/CONTAMINATION EXPERIMENT

1.0 EXPERIMENT IDENTIFICATION

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AFML/MBE
Wright-Patterson AFB, Ohio 45433

2.0 REQUIREMENT BACKGROUND

Response to STS Utilization Presentation (Response Sheet No. 31)

Supports SAMSO/DoD: STS Payload Interface Contamination Considerations

3.0 EXPERIMENT APPROACH

The purpose of the investigation is twofold:

(a) to determine the degree and nature of the contamination to which STS Shuttle Bay Payloads are exposed during various mission phases, i.e., during launch, deployment, on orbit and during recovery and reentry.

(b) to determine the effects of the LDEF space environment exposure on thermal control coatings and other satellite and space system materials.

Seven duplicate samples of various materials will be exposed. The types of materials are:

- Thermal Control Coatings
- Polished Metals
- Front Surface Mirrors
- Second Surface Mirrors
- Optical Flats (UV-IR)
- Polymeric Films
- Solar Cell Covers
- Insulation Blankets
- Adhesives
- Transparent Thin Films

One of the duplicate sets of materials is exposed through all of the operational phases of the mission. Each of the other sets is selectively exposed during one of the phases, i.e., prelaunch/installation, launch, removal/insertion, orbital, retrieval, and reentry/recovery.

The samples are returned to earth for diagnosis and the material property measurements shown in Table 3.0-1 are performed. The nature and extent of any surface film and/or particulate contamination will be determined and correlated with the various phases of the overall flight.

TABLE 3.0-1

MATERIALS PROPERTY MEASUREMENT

THERMO-OPTICAL	SOLAR ABSORPTANCE EMITTANCE
OPTICAL	TRANSMISSION SPECTRAL PROPERTIES, UV-IR
ANALYTICAL	AUGER ELECTRON SPECTROSCOPY ELECTRON SPECTROSCOPY FOR CHEMICAL ANALYSIS SECONDARY ION MASS SPECTROSCOPY FRUSTRATED MULTIPLE INTERNAL REFLECTION SPECTROSCOPY DIFFERENTIAL SCANNING CALORIMETRY ELLIPSOMETRY SCANNING ELECTRON MICROSCOPE
PHYSICAL	WEIGHT LOSS % ELONGATION TENSILE STRENGTH MODULI YIELD STRENGTH
ELECTRICAL	DIELECTRIC LOSS DIELECTRIC CONSTANT VOLTAGE BREAKDOWN

4.0 ASSESSMENT FOR STS FLIGHT

This experiment is well along in its planning for an LDEF flight and it is clearly a candidate for that kind of STS facility. The experiment is self-contained and requires no services from STS.

4.1 Experiment Considerations

4.1.1 Design Considerations

Mechanical

The experiment consists of two concentric disks. The upper disk can be stepwise rotated about the common center. The sample set that is exposed to the environment is mounted on this disk. The selectively exposed samples are mounted on the lower disk and are shielded from the environment by the upper disk. These samples are selectively exposed to the environment through slots in the upper disk as the upper disk is stepwise rotated.

The disk diameter is about 10 inches in radius and 3 inches deep deep and weighs between 20 and 30 lbs. This easily fits into a standard LDEF tray which is 37.5 inches long and 49.5 inches wide and comes in varying depths of 3", 6" and 12". Each standard tray can accommodate up to 175 lbs.

Electrical

A very small amount of power is required to operate the stepping motor. Power (less than one watt) is used during each step about ten times throughout the entire mission. The small energy requirement can readily be accommodated by batteries that will fit within the weight and volume capability of one standard tray.

No external command, telemetry or power is required.

Thermal

Passive thermal control will be included as part of the experiment.

Areas not covered by samples will be coated with adhesively bonded low outgassing metallized polymeric films, FEP/Ag or FEP/Al or silica fabric thermal control coatings. Individual samples will be allowed to reach their own equilibrium temperature.

Samples under the sector wheel will be kept cool because of the low temperature of the sector wheel cover.

Operations

This experiment can be flown in any LDEF orbit and imposes no operational restrictions on LDEF. The stepping of the motor is automatic and pre-programmed.

The ground support equipment is nominal and all unique equipment is provided by the experimenter. This includes contamination protection before selective exposure and equipment needed to test out stepping motor and logic. The handling and testing of this experiment appear relatively straightforward.

After recovery, the instrument and samples are returned to the experimenter for evaluation.

Reflight of the experiment is anticipated. This can be done by simply cleaning the instrument and installing new samples.

4.2 STP Integration Considerations

A conceptual layout of the STS-LDEF Multiphase Materials Performance/Contamination experiment is shown in Figure 4.2-1. As shown in the figure, the experiment fits easily into one standard tray. Also shown in the tray is the electronics for the stepping motor and batteries. This experiment uses so little power that it will probably be possible to share power with another LDEF experiment. In that case, the power could be supplied by an Electrical Power and Data System (EPDS) obtained from Langley by STP. These units occupy one-third of a tray and cost approximately $50,000 each.

Scheduled LDEF flights permitting 6-9 month exposures for this experiment are also shown. This experiment could be ready for a 1980 flight.

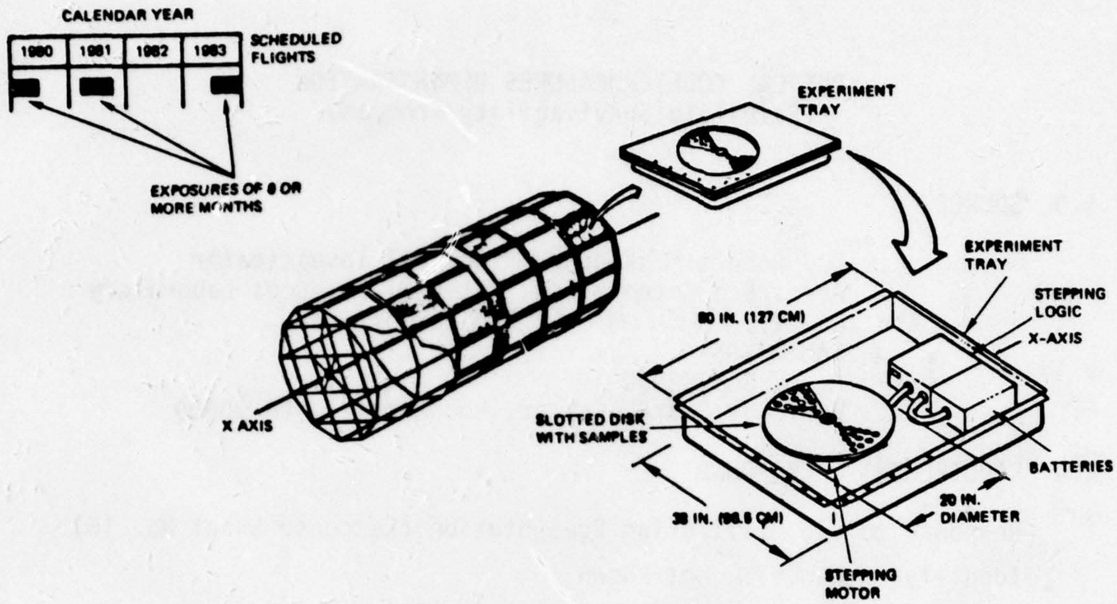

Figure 4.2-1. Multiphase Materials Performance/Contamination Experiment in Long Duration Exposure Facility

5.0 RECOMMENDATIONS AND COMMENTS

The STS-LDEF Multiphase Materials Performance/Contamination experiment is an excellent candidate for an LDEF flight in early 1980. No problems in integrating this experiment into LDEF are anticipated. The experiment can be accommodated easily in one standard LDEF tray and requires no STS services. The small amount of power need can be supplied by a dedicated battery or by an EPDS shared with another experiment.

OPTICAL COUNTERMEASURES DEMONSTRATION
(Satellite Survivability Program)

1.0 SOURCE

Dr. Robert M. Cooper, Principal Investigator
Aerospace Corporation, Material Sciences Laboratory
and Lt. Vic Slaboszewicz, Project Officer
SAMSO/YAS
P. O. Box 92960
Worldway Postal Center, Los Angeles, CA 90009

2.0 REQUIREMENT BACKGROUND

Response to STS Utilization Presentation (Response Sheet No. 16)

Identifying Number: not known

Details of experiment are classified.

3.0 EXPERIMENT APPROACH

3.1 Objectives

The objective of this test is to demonstrate the performance of optical countermeasures against lasers. A secondary objective is to obtain measurements of laser beam degradation caused by atmospheric turbulence and absorption. The countermeasures to be demonstrated are under development by the Air Force Materials Laboratory and by SAMSO.

3.2 Experiment Description

Tests will be conducted in conjunction with laser radar trackers situated at MIT Lincoln Laboratory (43°00'N, 72°00'W) and Holloman AFB (32°51'N, 106°06'W). At least 10 individual encounters with each of the two test sites will be required. The orbital period, inclination, and ascending node should be selected to maximize the number of encounters between the payload and the two test sites.

The tests will consist of acquiring, tracking, and illuminating the payload package with the laser tracker. Measurements of intensity will be made with radiometers located on the payload package and on the Shuttle Orbiter during operation of the optical countermeasures. Individual encounters will last approximately three to five minutes. Typically, there will be four encounters per day.

3.3 Orbit

The orbit should be circular with 400 km maximum altitude and at least 45 degree inclination. Polar or near polar inclination is acceptable. As described previously, the ascending node,

inclination, and period should be selected to optimize the number of passes over the two laser test sites. Line-of-sight elevation angles during the tests are to be at least 60 degrees. The flights should be conducted in late summer or fall so that cloud cover over the MIT Lincoln Laboratory site is at least minimum.

3.4 Configuration

The configuration of the test equipment relative to the Shuttle orbiter is shown in Figure 3.1. The payload package must be deployed on a boom away and downward from the Shuttle Orbiter and separated by 15 meters or more. The weight and volume of the boom-mounted package are 50 kg and 70 x 70 x 50 cm^3. The package may further deploy short, retractable booms 2 to 3 meters long.

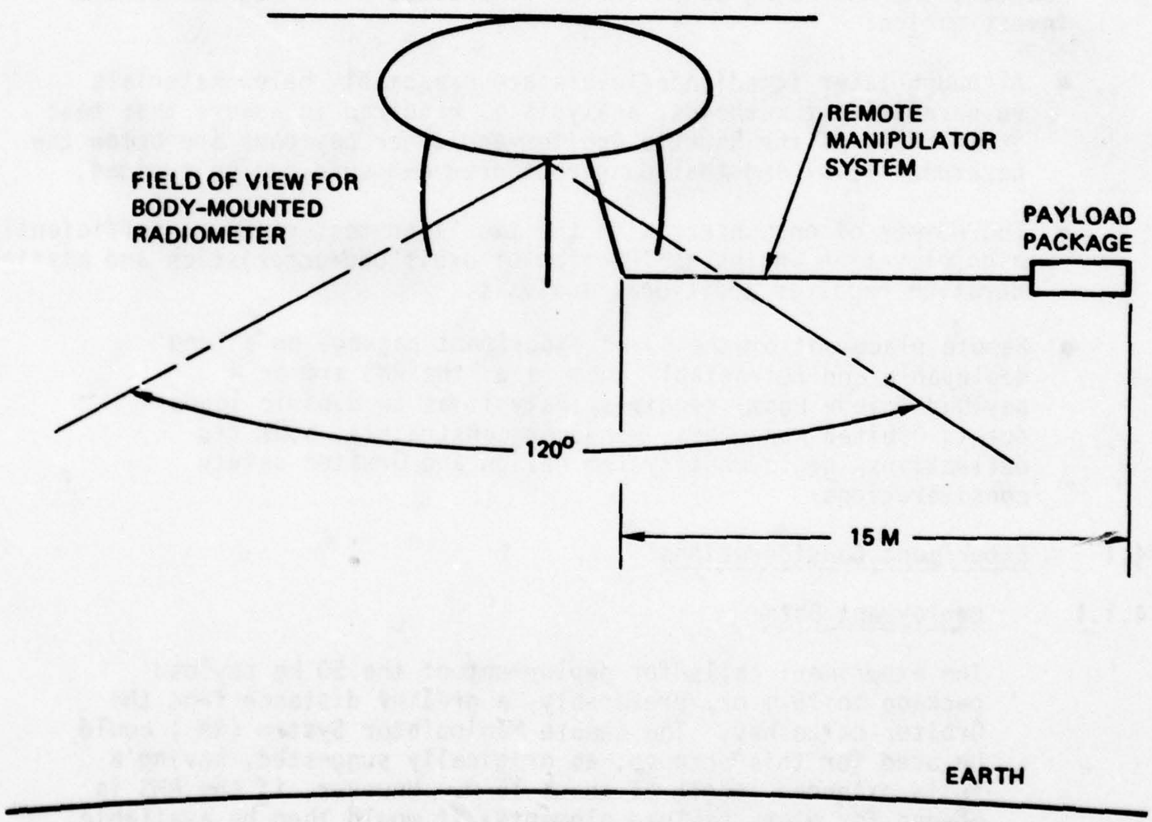

Figure 3-1. Configuration on Shuttle Orbiter of Optical Countermeasure Demonstration

There will be three small radiometers hard-mounted on the Orbiter that require a 60-degree half-angle, downward-looking field of view. These packages are 12.5 x 15 x 17.5 cm^3 in dimension, weigh 3 kg each, and should be as widely distributed on the Orbiter as possible.

Other requirements are:

Power:	50 W @ 28 VDC
Telemetry:	40 digital channels @ 1 sec
	5 wideband analog channels @ 10 KHz
Command:	10 momentary commands

4.0 ASSESSMENT FOR STS FLIGHT

No major problems are anticipated in carrying this experiment onboard the Shuttle Orbiter, possibly as an add-on or "piggyback" payload. Its small weight and compact size (when stowed) and its compatibility with orbital altitudes and inclinations of many typical Shuttle missions facilitate accommodation of this experiment. Demands on crew operation are minimal.

However, the following areas are of some concern and require further investigation:

- Although laser irradiance levels are presumably below materials vulnerability thresholds, analysis is required to assure that test irradiances of the Shuttle Orbiter and other payloads are below the hazardous level and that dangerous crew exposure can be avoided.
- The number of encounters with the two laser test sites at sufficiently high elevation angles as function of orbit characteristics and mission duration requires additional analysis.
- Remote placement of the 50 kg experiment package on a long deployable and retractable boom (e.g. the RMS arm or a payload-unique boom) requires analysis as to dynamic loads due to Orbiter maneuvers, maneuver constraints, boom tip deflections, deployment system design and Orbiter safety considerations.

4.1 Experiment Considerations

4.1.1 Deployment Boom

The experiment calls for deployment of the 50 kg payload package to 15 m or, preferably, a greater distance from the Orbiter cargo bay. The Remote Manipulator System (RMS) could be used for this purpose, as originally suggested, having a fully extended length of about 15 m. However, if the RMS is needed for other payload elements, it would then be available to the laser experiment only during a part of the mission. The time allocation depends on the overall Orbiter payload composition and requires further study.

To avoid RMS allocation conflicts, a second RMS arm could be installed to be assigned exclusively to the laser experiment. However, this would accrue extra cost and weight which would be chargeable to that experiment.

Another alternative would be the use of a dedicated, payload-unique deployment boom permanently attached to the experiment package. This would avoid the remotely controlled attachment/detachment procedures necessary with RMS, eliminate time allocation conflicts and permit payload deployment to distances greater than 15 m by appropriate boom design. The boom weight, including deployment mechanism, would be only 25 to 50 lb, compared with 800 to 900 lb for the RMS and end effector.

Possible candidates for this application would be existing coilable lattice booms (Astromast, manufactured by SPAR Aerospace Products, and Able Boom, manufactured by Able Engineering Co., both of Santa Barbara, Calif.) consisting of three continuous fiberglass/epoxy longerons with transverse battens and stiffening cables (Figure 4.1-1). These booms are designed for applications such as lightweight deployable antenna masts, as instrument support booms on spacecraft and for deployment of large solar arrays. A lightweight solar array extension boom currently being developed by Able Engineering under Lockheed contract has dimensions and characteristics that could be used for the laser experiment application:

Boom length:	105 ft (32 m)
Cross section diameter	14.5 inches
Weight	36 lb.
Bending strength (M critical)	100 ft-lb
Bending stiffness (EI)	2.5×10^7 16 in^2

However, depending on the desired deployment distance and the magnitude of the bending moments exerted on the cantilevered boom during orbiter roll and yaw maneuvers, a boom design of larger cross section diameters and greater bending strength may be required, as discussed below. The concern is with boom integrity under maximum acceleration loads rather than with tip deflections which can be minimized by refraining from thruster operation sometime prior to and during laser test site encounter events.

4.1.2 Boom Bending Moments Due to Orbiter Maneuvers

For a long cantilever boom with a 50-kg tip mass the dynamic bending loads due to Orbiter rotational maneuvers are more severe than those due to translational maneuvers. Maximum rotational accelerations during RCS thruster firing are 1.5 deg/sec^2 (for the 900 lb primary thrusters) and 0.04 deg/sec^2 (for the 25 lb vernier thrusters) according to data from the Shuttle Payload Accommodations Handbook, JSC 07700, Volume XIV, Revision D (Change #15), p. 3-38. With boom deployment in or near the direction of the Orbiter y-axis, the maximum angular accelerations in roll and yaw are of primary concern.

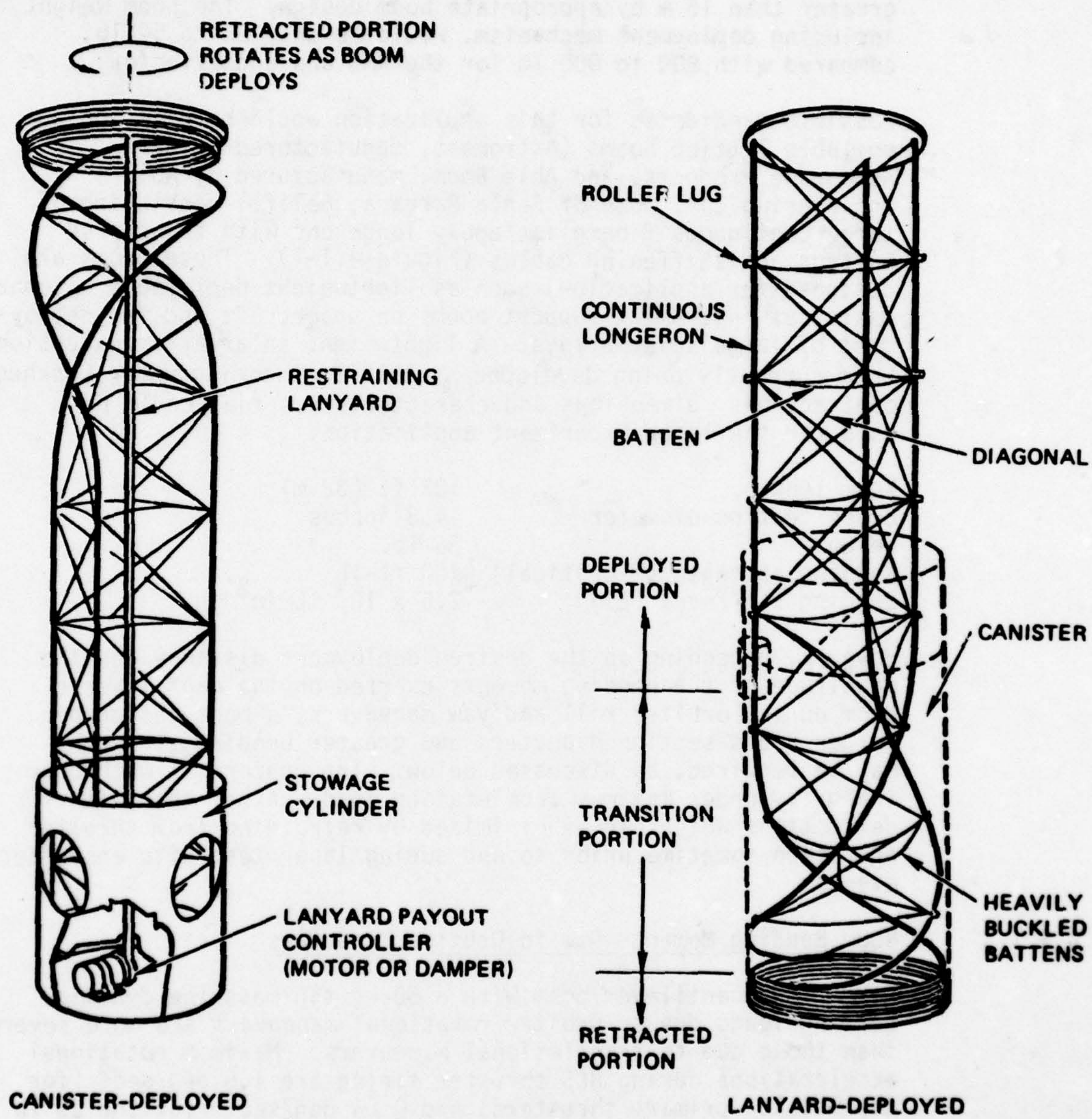

Figure 4.1-1. Continuous-Longeron, Coilable Lattice Boom (Courtesy Able Engineering Co.)

Table 1 lists maximum bending moments due to maneuver loads acting on (a) the fully extended RMS arm (15 m length) and (b) lattice booms deployed to various lengths (15 to 30 m). The bending strengths of these booms also are indicated. Note that the load due to primary thruster firing slightly exceeds the bending strength of the RMS, with 60 percent of that load being contributed by the heavy RMS arm itself.

TABLE 1

Bending Moments Due To Orbiter Rotation Maneuvers For Various Deployment Boom Types and Lengths

(Assumed Tip Mass 50 kg)

Boom Type	Bending Strength (ft.lb)	Deployment Distance (m)	Max Bending Moment To Rotational Maneuvers (ft-lb) Primary Thrusters	Vernier Thrusters	Fraction of Moment Contributed by Boom Mass
RMS Arm	500	15	563	15.0	0.60
14.4" Lattice Boom	100	15	227	6.0	0.013
		30	920	24.5	0.026
29" Lattice Boom	800	15	236	6.3	0.051
		26	730	19.4	0.085
		30	992	26.4	0.097

The 29" lattice boom deployed to 26 m has sufficient bending strength to withstand primary thruster firing.

Lattice booms of much smaller diameter can withstand loads due to vernier thruster firing. Since for a given tip mass and rotational acceleration, the critical bending moment is proportional to the square of the boom length, it is seen that the 14.5" boom could be deployed to about 60 m before the bending strength of 100 ft-lb is exceeded by vernier thrust dynamic loads.

Based on these results, the RMS arm with a 50-kg tip mass should not be fully extended to avoid excessive bending loads during primary RCS thruster firing. If a dedicated lattice boom of large diameter (30") is contemplated to support the experiment package it could be safely deployed to 26 m. Deployment of the package to only 15 m would be possible with a boom of 19 inch diameter.

Restriction of Orbiter maneuvers to the use of vernier thrusters only would reduce the bending loads by a factor of nearly 40 and thus permit the use of booms of much smaller diameter, but would be operationally unattractive.

To avoid excessive bending moments the boom can be retracted whenever the primary thrusters are to be used for maneuvering the Orbiter. The repeated retraction/deployment cycles that would be necessary during the mission would complicate the operational sequence and may pose reliability problems. This operating mode should therefore be avoided.

4.1.3 Encounters of the Two Laser Test Sites

Careful selection of Shuttle orbit characteristics is required to maximize the number of test site encounters at elevations greater than 60 degrees. Figure 4.1-2 shows a set of daily Orbiter ground tracks for 45-degree orbit inclination. Because of its proximity to the maximum latitude of these tracks, the Lincoln Lab test site is encountered once to twice daily in spite of the small visibility circle (radius = 4 degrees) corresponding to elevation angles ≥ 60 degrees. At the lower latitude of the Holloman AFB test site the local ground track inclination is steeper and, consequently, the average number of daily encounters is appreciably smaller.

By proper choice of orbit parameters the day-to-day drift of the ground track can be adjusted such that during a short Shuttle orbit mission (less than 7 days), the number of daily Holloman encounters can be improved without noticeably affecting the Lincoln Lab encounter frequency, because of the ground track pattern geometry. An orbit inclination increase to about 48 degrees raises the Holloman encounter frequency but lowers the Lincoln Lab facility encounters. Conversely, a reduction of the orbit inclination to 42 or 43 degrees increases the frequency of Lincoln Lab encounters at the expense of Holloman encounters. According to the SAMSO Project Office, the Lincoln Lab encounters are of greater importance than those of Holloman, and this is aided by the more advantageous geographical location of Lincoln Lab relative to the ground track pattern.

The total number of useful encounters would be much increased if the experiment were to be performed at elevation angles less than 60 degrees, as indicated by the size of the visibility circles in Figure 4.1-2.

The geometrical factors discussed in the preceding paragraphs also indicate that polar or near-polar orbits are less well-suited to produce an adequate number of test site encounters than orbits of intermediate inclination.

4.1.4 Operation Restrictions

4.1.4.1 Crew Safety

A principal concern is that of crew safety during laser irradiation of the Shuttle Orbiter from the ground. Even with irradiance levels sufficiently low to avoid material damage to the Orbiter and its payloads, crew members must probably be protected against

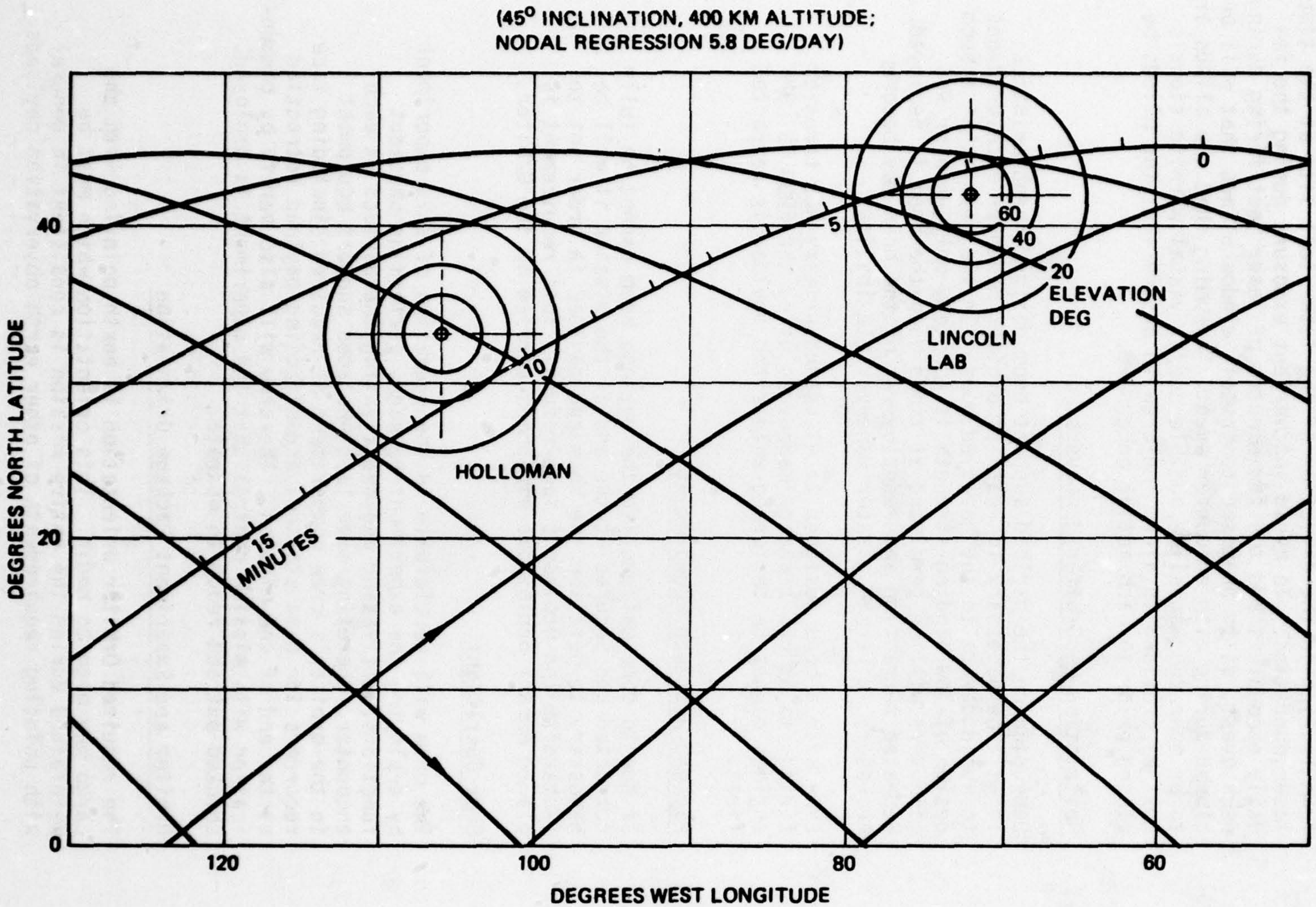

Figure 4.1-2. Orbiter Ground Tracks on Third Day from Launch and Visibility Contours of Lincoln Lab and Holloman AFB

direct exposure and especially against eye injury that could result from looking in the direction of the laser test site at the time of laser operation. To avoid inadvertent exposure during the few daily encounters and the few minutes of laser test firing during each event, it is proposed to install window blinds that will be closed during each encounter event. Assuming that the blinds are to be operated manually, audible and/or visual warning signals must be provided to alert the crew to assure that the blinds be closed prior to each active encounter.

4.1.4.2 Restriction on Orbiter Maneuvers

Depending on the payload support boom design characteristics it will be necessary to restrict orbiter maneuver accelerations to avoid damage to the deployed boom. In the event that a boom design of low bending strength is adopted, only vernier RCS maneuvers will be permitted at times when the boom is deployed. Repeated retraction and redeployment of the boom may become necessary to permit greater maneuver flexibility.

Even with a boom designed to withstand primary RCS thruster firing, major orbit change maneuvers using the 6000 lb OMS engines cannot be performed unless the payload is retracted first.

4.1.4.3 Payload Jettison Requirement

If due to some malfunction the payload boom cannot be fully retracted and secured at the end of the mission it will be necessary to jettison the boom and payload in order not to jeopardize the Orbiter's safe return. This requirement is placed on any deployable equipment carried by the Orbiter.

4.1.5 Crew Operations

The crew will participate in the operation of this experiment by deploying the experiment package, performing checkout functions, activating and deactivating the payload at each encounter, operating experiment-related support equipment in the orbiter's crew compartment as required (including tape recorders for data storage) and effecting payload retraction at the end of the mission. The crew will also verify by communication with mission control that the experiment is deployed, checked out and ready to operate.

4.1.6 Orbiter and Experiment Package Orientation

The required Orbiter orientation is earth pointing with the cargo bay open to nadir. This orientation which must be maintained during the entire mission is consistent in general with pointing requirements of other earth observation payloads.

Details of the experiment package orientation (e.g. the need to keep it pointed at the laser test site during an overflight event) have not yet been defined. Orientation changes, if required, would best be provided by the experiment package itself.

Orientation requirements are not critical. In the absence of dynamic deformation of the deployment boom (no RCS maneuver), orientation requirements such as $\pm$ 1 degree of pointing accuracy can be readily met by the proposed boom design.

Thermal deformations of the fiberglass/epoxy lattice boom are minor and can be established by on-board measurements if desired.

4.2 STS Integration Considerations

4.2.1 Conceptual Layout

Figure 4.2 shows a conceptual layout of the experiment package and payload-unique deployment boom in stored and deployed configuration on the Shuttle Orbiter. The equipment is placed on a Standard Test Rack, mounted in the forward part of the cargo bay, such that extension of the experiment package to one side of the Orbiter (starboard) provides as much lateral clearance as possible from the cargo bay and the wing structure and avoids obstruction of RMS motion. The fully-deployed 30-inch diameter lattice boom is assumed to extend to 85 ft (26m) length. The stowed boom contained in a 75 inch by 34 inch diameter stowage and deployment canister and the experiment package (28 x 28 x 20 inches) attached to it are stowed in a retention cradle parallel to the Orbiter x-axis. From this position it is rotated to an orientation normal to the x-axis, and slanted with respect to the x-y plane, before the lattice boom is deployed. In addition to the deployed experiment package three radiometers are carried by the orbiter spaced at 20 ft intervals along the cargo bay (not shown in drawing).

4.2.2 STS Interfaces

Mechanical interfaces with the Shuttle Orbiter were discussed above and involve the experiment mounting and retention fixtures plus the RMS arm and end effector, unless a dedicated deployment boom is provided for this experiment.

Electrical interfaces include the STS power supply, command channels, data handling and telemetry, and crew display panels that present payload status data, caution and warning indications. All of these support requirements are quite modest and can be readily accommodated by the Shuttle power supply and avionics subsystems. Of particular interest are the data handling and telemetry interfaces which will be discussed below.

4.2.3 Data Handling and Telemetry

The telemetry requirements of the experiment, stated in Section 3.2, translates into a maximum bit rate of 1.5 Mbps during the short active operating periods of several minutes, averaging four times per day. The total data volume for a 7-day mission is estimated to be of the order of 2.5×10^9 bits. The Shuttle data handling subsystem provides adequate capacity to record all digital and analog channels of the payload data either for temporary storage, with intermittent data dump to ground stations, or for post-flight data retrieval and evaluation. Channel capacity via Ku-band link to TDRSS, with bit rates of 2 Mbps and 50 Mbps, is adequate to provide real-time telemetry of payload data to the ground. Details of data handling requirements, formats, interface equipment and operating sequences for this experiment still need further definition.

4.2.4 Cost Considerations

The small size and weight of this payload permits accommodation on the Shuttle Orbiter at a minimum launch charge. Use of a dedicated RMS arm (at a weight of 800 to 900 lbs), which would greatly increase the installation cost and transportation charges, can be avoided by the approach discussed in Section 4.1. The cost savings may be of the order of $1 million.

5.0 RECOMMENDATIONS AND REMARKS

The experiment can be readily integrated with and operated from the Shuttle Orbiter because of its small size and weight, its compatibility with orbit characteristics typically used by the Shuttle, its modest demand on crew time and skills, infrequent operating times and modest pointing requirements.

It is recommended that questions of possible interference with other experiments and possible hazards to the crew due to intensive laser illumination for short time periods be further investigated to define adequate safety and protection procedures and equipment.

LOW LEVEL ASSESSMENTS

The "low level" assessments consist of a brief statement describing the potential accommodation of the subject experiment by the STS and one of the available payload carriers.

The experiments evaluated were those that remained after more than 16,000 active Work Unit Summaries (Form 1498's) were reviewed by TRW's specialists.

The screening initially was performed to determine if the experimenters' objectives would be enhanced by a space experiment. Once this conclusion was reached, the experiment was assessed for compatibility with the STS. Since the information contained in the Form 1498 is, at best sketchy, it is possible to misinterpret the space experiment that might arise from a research work unit.

However, the combination of the "medium" level and "low" level assessments covers a wide variety of space experiments and should provide the DoD scientific community with examples of the utility of STS as an experiment carrier.

There are 43 classified experiments included in this section which appear to have a compatibility with the STS. Discussions of these has not been included because of their classification.

Several "low level" assessments follow as examples.

LISTING OF AGENCIES REPRESENTED IN THE LOW LEVEL ASSESSMENTS

AIR FORCE

- Office of Scientific Research
- Space & Missile Systems Organization
- Avionics Laboratory
- Applied Physics Laboratory
- Materials Laboratory
- Rome Air Development Center
- Geophysical Laboratory
- Flight Dynamics Laboratory
- Weapons Laboratory
- Electronics Systems Division
- Rocket Propulsion Laboratory
- Aerospace Corporation

NAVY

- Chief of Naval Operations
- Office of Naval Research
- Naval Sea Systems Command
- Naval Electronics Systems Command
- Naval Air Systems Command
- Naval Research Laboratory
- Naval Weapons Center
- Naval Surface Weapons Center
- Naval Ship Research and Development Center
- Naval Electronics Laboratory

ARMY

- Army Electronics Command
- Army Development and Readiness Command
- Army Missile Command

DoD

- Defense Mapping Agency
- Defense Nuclear Agency

LOW LEVEL EXPERIMENT ASSESSMENT EXAMPLES

ID No. (Response Sheet or Assessment #)	Principal Investigator	Agency	Title	STS Facility (Spacelab, LDEF, etc.)	Assessment Comments
DF039430	F. H. Pollak Yeshiva University New York, NY	Air Force Office of Scientific Research	Growth of Homogeneity Characterization of Mercury Cadmium Telluride Crystals	Spacelab Pallet	Currently laboratory experiment in liquid phase epitax growth. Good candidate for zero-G Spacelab materials processing.
DF680130	P. Peterson Honeywell Bloomington, NM	AFML	Gallium Phosphide Materials Development for Satellite Attitude Sensors	Spacelab Pallet	Skylab experiments on similar processes showed beneficial results.
DF901150	Robert H. Eather Keo Consultants Newton, MA	RADC	Imaging All Sky Photometer	Pallet	Instrument development for aircraft flights. Could be flown on STS Orbiter mission with a pointing system.
DF249440	Joseph P. McIsaac	AFGL	Satellite Density Measurements using Ionization Gauges and Laser Sounding	Pallet or Free Flyer	Several density measuring instruments suitable for STS Orbiter or low altitude free flyers.
DN480096	B.S. Yaplee NRL	Defense Mapping Agency	Satellite Radar Altimetry	Free Flyer	Data Analysis of altimeter outputs. Many opportunities for STS launched altimeter experiments exist. GPS can provide very accurate ground tracks.
DN920018	D. P. McNutt	Naval Research Lab	Far IR Environmental Limits to Military Systems	Pallet or Free Flyer	Current IR instrumentation development. Developed instrument would need earth pointing platforms. Well suited to STS flights.
DAOF1752	M. D. Kays	ECOM Atmos. Science Lab	Atmospheric Waves, Their Nature and Effects on Army Operations		Possible STS Experiment
DAOE9212	J.H. Perepezko University of Wisconsin Madison, WI	DARCOM Army Research Office	Solidification of Highly Undercooled Liquid Metals and Alloys	Spacelab Pallet	This project has one of the most important potentials for space processing to date. Numerous experiments have shown anticipated benefits.

RESULTS AND CONCLUSIONS

RESULTS

Approximately 17,000 current research and technology Work Unit Summaries (DoD Form 1498) were screened for applicability to space experimentation. 994 of these were classified.

65 response sheets were received as a result of the presentations at DoD establishments.

From all of these, 175 were determined to have probable application to space flight experimentation using the STS. 132 of these were assessed by TRW to determine what payload carrier is appropriate for each experiment and the best method for its integration.

In the following tabulation, all of the investigations which were assessed are categorized by carrier vehicle and by type of investigation.

ASSESSMENT DATA

	ATTACHED	LDEF	FREE FLYER	MORE THAN ONE
SCIENCE & MEASUREMENTS	14 / 12	2 / 1	3 / 16	2 / 23
DEVICES	4 / 14	0 / 0	0 / 2	0 / 5
MATERIALS	3 / 21	2 / 6	0 / 0	2 / 0

LEGEND: MEDIUM LEVEL / LOW LEVEL

CARRIER:

ATTACHED	USE OF SPACELAB, STR OR OTHERWISE MOUNTED ON OR IN THE ORBITER.
LDEF	MAKING USE OF THE LDEF.
FREE FLYER	REQUIRING A FREE FLYING SPACECRAFT.
MORE THAN ONE	COULD BE PERFORMED ON MORE THAN ONE OF THE ABOVE VEHICLES.

TYPE:

SCIENCE & MEASUREMENT	INVESTIGATIONS FOR MEASUREMENT OF BASIC PHYSICAL PHENOMENA.
DEVICES	EXPERIMENTS FOR DEVELOPMENT AND SPACE QUALIFICATION OF SPECIFIC EQUIPMENT.
MATERIALS	INVESTIGATIONS AIMED AT IMPROVEMENT OF MATERIALS.

These categorizations are summarized below:

STATISTICAL SUMMARY (ALL ASSESSMENTS)

BY CARRIER		
ATTACHED	68	
LDEF	11	
FREE FLYERS	21	
MORE THAN ONE	32	
BY TYPE		
SCIENCE AND MEASUREMENTS		73
DEVICE QUALIFICATION OR TEST		25
MATERIALS IMPROVEMENT		34
POSSIBLE MATERIALS PROCESSING IN SPACE (23)		
EFFECTS OF SPACE EXPOSURE ON MATERIALS (11)		

29 DoD organizations are represented in the 175 investigations listed in this report.

The investigations that were assessed at medium level were all found to be readily performable with the STS, making use of one or another payload carrying vehicle. These are summarized in the tabulation below. Of the three that must integrate directly with the Orbiter, one is small, passive, will want to fly frequently, has only a mechanical bonded interface; one has such large power and heat rejection requirements that it might not be able to work through a carrier; one has special deployment problems.

RESULTS FROM MEDIUM LEVEL ASSESSMENTS

- 3 EXPERIMENTS NEED FREE FLYERS
- 4 USE THE LDEF
- 21 REMAIN ATTACHED TO SHUTTLE
  - 16 NEED SERVICES, EITHER STR OR SPACELAB
  - 3 INTEGRATE DIRECTLY WITH ORBITER
  - 2 NEED A MULTIPURPOSE FURNACE FACILITY

Performance of these investigations, in many cases, depends on the development of specialized flight support equipment such as pointing platforms, extendable booms, and materials processing facilities. Six investigators need some type of pointing system to achieve more precise pointing or stability than the Orbiter can achieve. Three need small satellites to make ancilliary measurements in conjunction with the Orbiter mounted equipment. Five need masts or booms to deploy instruments or other equipment away from the Orbiter payload bay. In most cases, the investigations that need this flight support equipment are closely parallel to proposed NASA investigations. Much of this equipment could have joint usage once developed.

Within the work units that were assessed at low level were many investigations that appear to be quite similar, from an implementation standpoint, to one or another of those assessed at medium level. For these, there is strong confidence that they are readily performable with the STS and the payload carriers now under development. There are others that reflect data studies or phenomena modeling contracts. These are judged to need data from space flight and, should they be continued into the STS era, such data can be generated by the many flights now envisioned. Additionally, some work units are concerned with design studies for spacecraft equipment, or instruments. If these are continued, there could arise a need for flight test and qualification.

This review showed that a considerable amount of basic materials research is being performed within DoD. Many of the areas of research appear to be on subjects for which NASA's MPS program has demonstrated a strong possibility of improved materials, or better understanding of the basic processes, through space experimentation in a "zero"-gravity environment. Nevertheless, there was no evidence in the research work unit summaries that space experimentation is under active consideration. This impression was reinforced through discussion with several contacts within the DoD materials community and by the fact that no scientists known to be working for DoD were applicants on NASA's Announcement of Opportunity for materials processing investigations.

Examination of the work units suggests that DoD organizations who sponsor materials research, should investigate those areas in which "zero"-gravity experimentation could assist. Serious consideration should be given to the following:

a. The potentials of novel and unique materials breakthroughs, to be incorporated in the sensor and communications technologies of the next decade, suggest a careful and thorough exploitation should occur by the DoD sponsored R&D community.

b. DoD exploitation of low gravity processing environments is an extremely attractive opportunity based upon NASA providing the lead funding for baseline MPS capabilities.

c. It can be assured that the experiments selected for space research match DoD individual technical objectives only by DoD sponsorship of space experiments.

   These investigators could use the NASA capabilities as they evolve.

d. It may be desirable, however, to develop major MPS facilities unique to focused DoD needs as they become identified. To date, the general requirements appear to match the contemplated NASA program scope. Developing minor experiment unique flight apparatus may be necessary. This, along with sustained support of the on-going ground research projects, should be viewed as the minimum cost of participation.

e. Collaborative scientific teams should be formed to combine desirable capabilities and achieve critical effort sizes for sustained pursuit of research objectives.

CONCLUSIONS

Based on presently active research and development work units, the following conclusions can be drawn:

a. A considerable amount of traffic of DoD space flight experimentation can be projected for the STS flight era.

b. Most DoD experiments, not specifically requiring free flying spacecraft, will need to make use of one or another of the payload carriers that are being developed. Few experiments can, or should, interface directly with the Shuttle Orbiter.

c. Many experiments require flight support equipment of a specialized nature in addition to the payload carrier. However, much of such equipment is soon to be under development by NASA and could fulfill DoD requirements.

d. When an experiment has been approved for development, the investigator should be given assistance from a payload accommodation group to assist in achieving a low cost approach for its development and to improve overall mission efficiency.

e. Liaison between DoD and NASA materials science areas should be improved to assure consideration of DoD peculiar requirements for materials research and to promote potential collaboration in flight facility development.